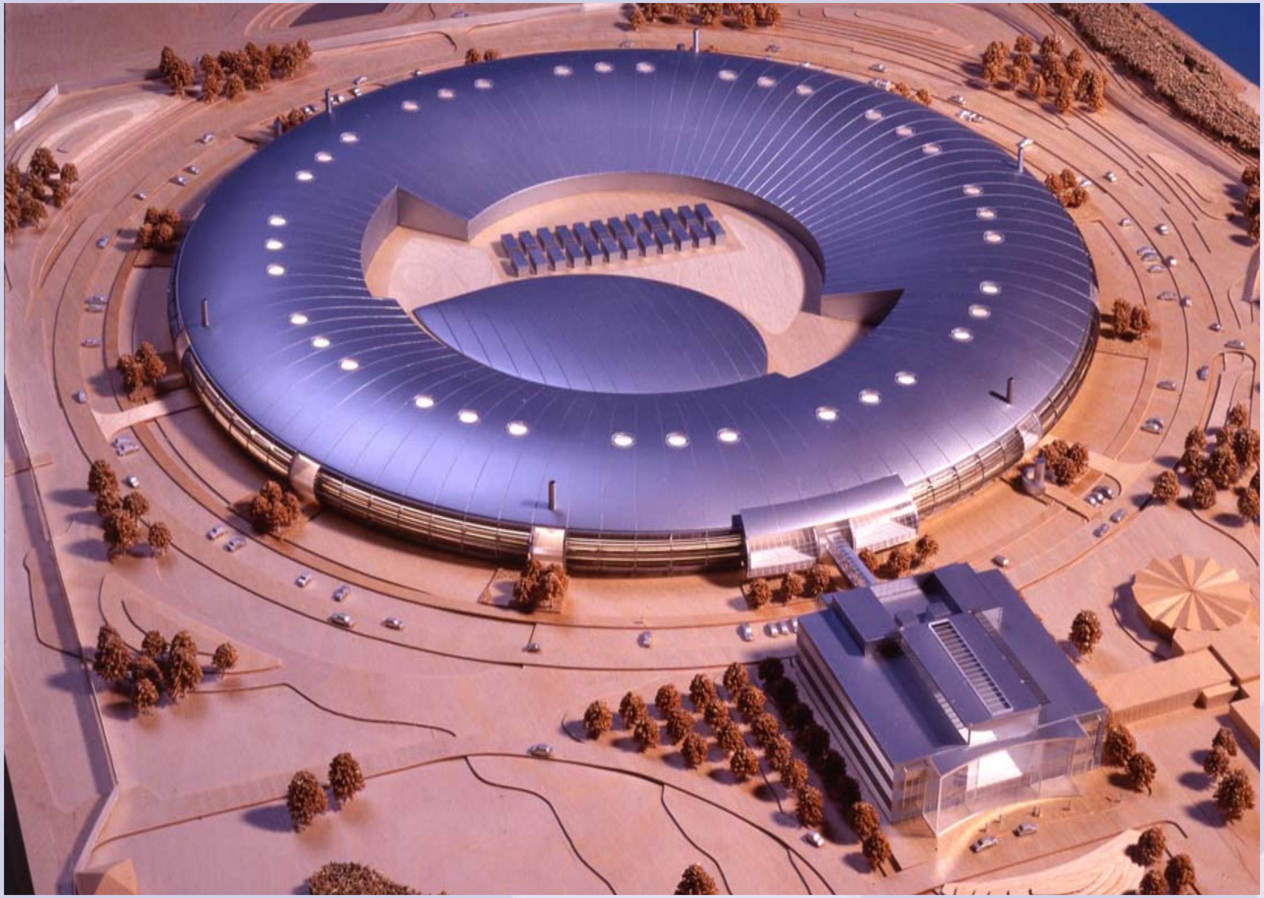
Diamond Mech Eng’g Details



May 2004

diamond

Contents

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I. Diamond Light Source Shareholders

CCLRC

86 %

The Council for the Central Laboratory of the Research Councils (CCLRC) is a non-departmental public body of the Office of Science and Technology, part of the Department of Trade and Industry

The Wellcome Trust

14 %

World's largest biomedical research charity whose mission is

'To foster and promote research with the aim of improving human and animal health'

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II. Diamond Design Criteria

- Large capacity for Insertion Device beamlines

  eighteen 5m straights and six 8m straights
- High brightness from undulators optimised in the range 0.1-10 keV, extending to 15-20 keV, 7mm min gap
- High flux from wigglers from 20-100 keV
- Cost constraint

➔ "medium" energy of 3 GeV and 300 mA current

➔ relatively large circumference (562 m) with (24) DBA cells

➔ extensive use of in-vacuum undulators

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Technical Challenges for the Machine

- **alignment: 0.1 mm magnet positioning tolerance**
- **achieving the required low vacuum pressures**
- **large number of small gap and in-vacuum insertion devices** (effect on vacuum, and machine operation)
- **superconducting radio-frequency system**
- **continuous "top-off" injection**
- **electron beam stability -** settlement, thermal effects, vibrations etc.

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III. Engineering Organization
(Partial List of Contacts)

Area of Responsibility	Staff Member	E-mail (@diamond.ac.uk)
Head of Engineering	Jim Kay	j.kay@
Girders, Magnets, Vac Chambers	Nigel Hammond	n.p.hammond@
Insertion Devices	Charles Thompson	Charles.Thompson@
Front Ends	Don Clarke	d.g.clarke@dl.acluk
Buildings and Services	Rick Mason	
Injector	Graham Duller	Graham.Duller@
Elect Eng'g / Motion Control	Andy Bell	abell@
Beamline Mech Eng'g	Andrew Peach	andrew.peach@
Beamline Mech Eng'g	Andrew Marshall	andrew.marshall@
Power Supplies Elect Eng'g	Vance Buckley	v.buckley@
Mechanical Design	Ron Godwin	Ron.Godwin@
Mechanical Design	Tony Gardner	a.gardner@
Mechanical Design	Roger Holdsworth	r.holdsworth@
Mechanical Design	Kevin Collins	kevin.collins@
Electrical Project Engr	Simon Lay	simon.lay@
Mechanical Engr	Joe Williams	Joe.Williams@
Front Ends	John Strachan	j.strachan@dl.ac.uk

Color key: blue= presentation given

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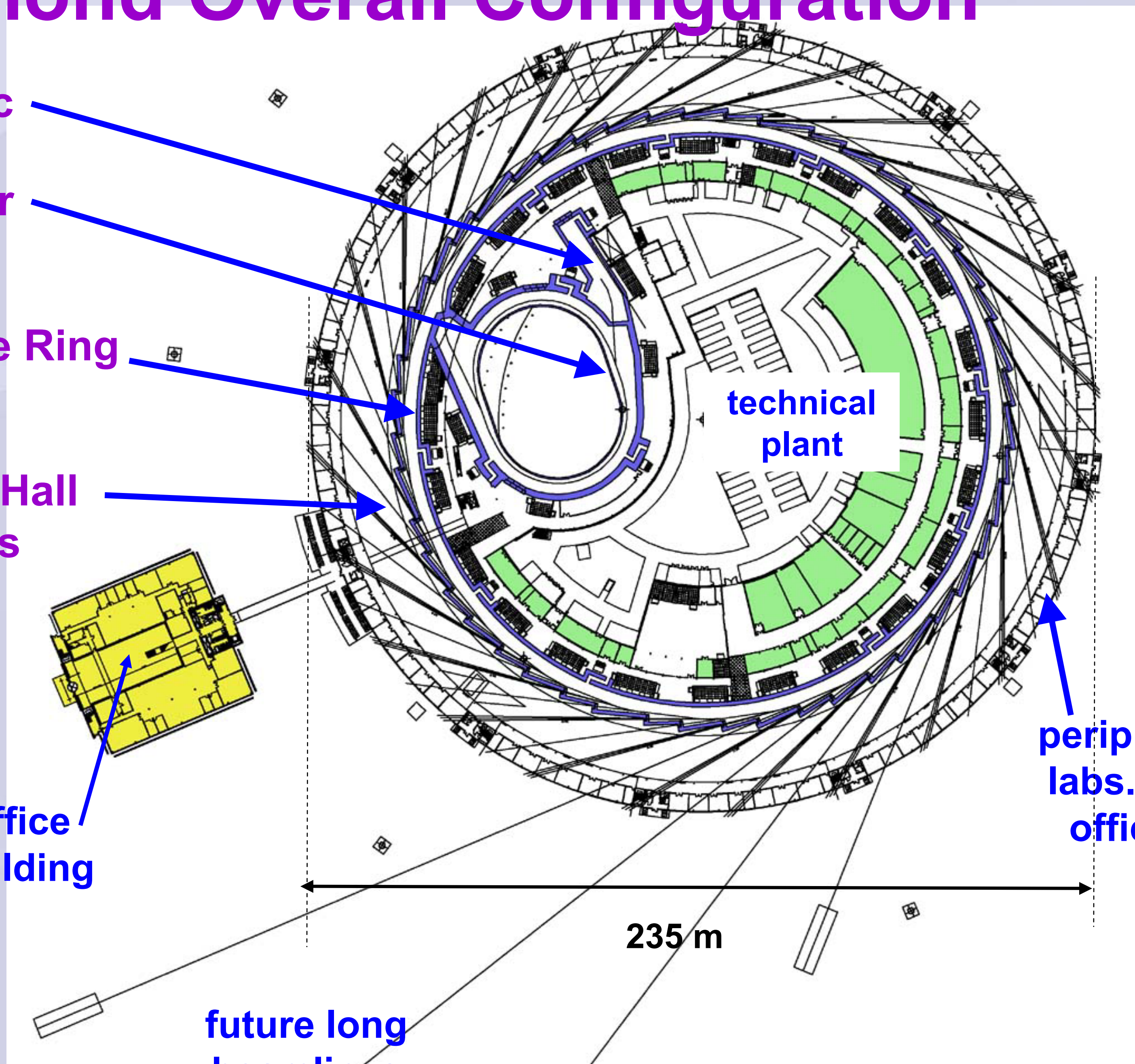
Eng'g Organizational Structure

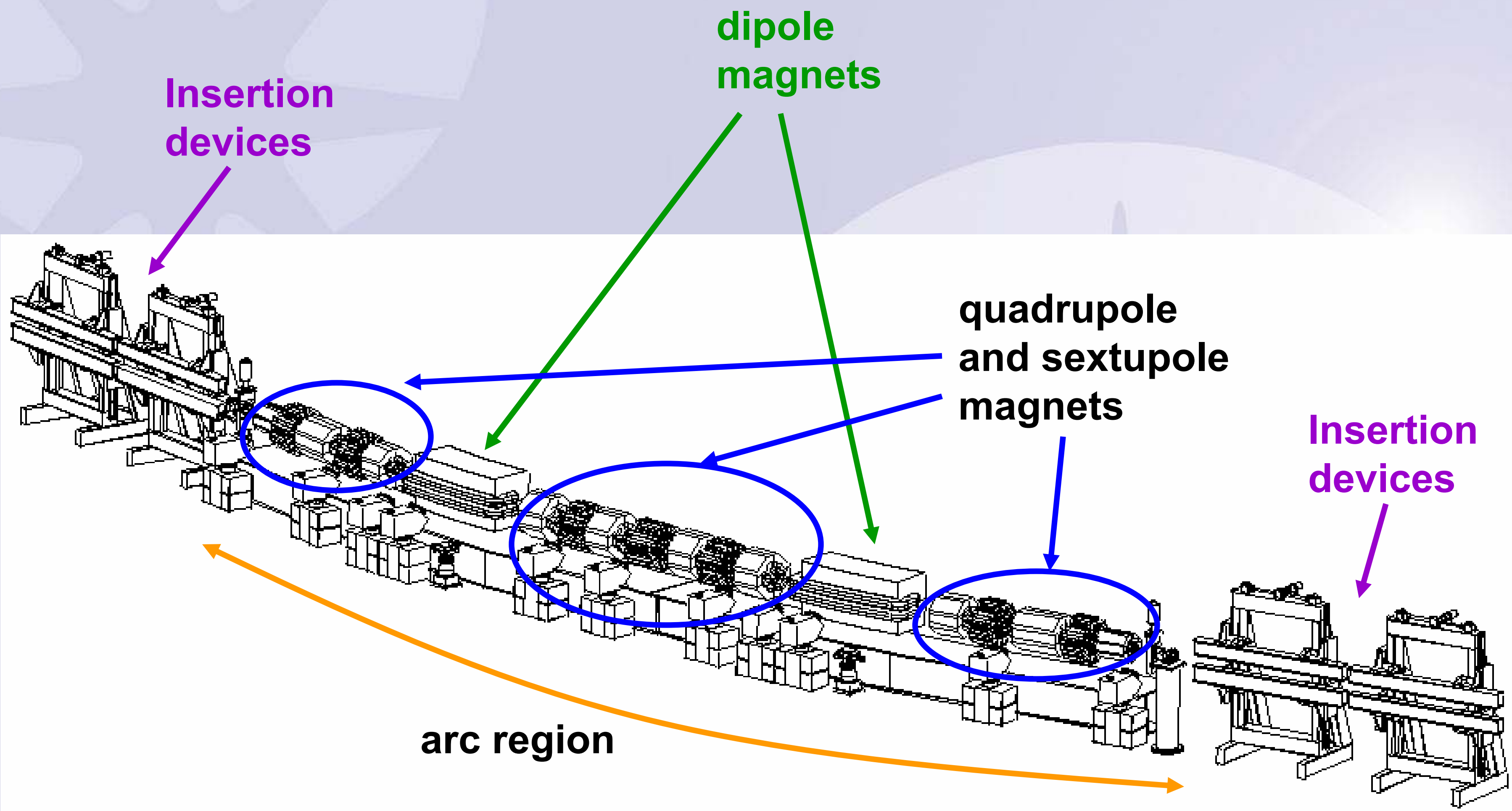
- Survey team: 6 (4 + 2 contract)
- Electrical team: 15 (7 + 3 CLRC + 5 contract)
- Mechanical team: 29 (13 + 8 CLRC + 8 contract)
- Technician staff : 5
- Total Technical Staff: 55

Meeting with Diamond ME Staff

IV. Diamond Overall Configuration



Diamond Magnet "Lattice"



Diamond Phase I: Machine & 7 Beamlines

- **Protein crystallography (3 beamlines, # 8, 9, 10)**
  For the determination of the structure of macromolecules with rapis sample through-put.
- **Extreme conditions (Beamline 1)**
  Study of materials at very high temperatures and pressures, typical of planetary interiors and industrial processes.
- **Materials and magnetism (Beamliine 6)**
  Study of materials including magnetic systems, high temperature superconductors
- **Microfocus (Beamline 13)**
  chemical imaging and structural studies of complex multicomponent systems with sub-micron resolution
- **Nanostructures (Beamline 14)**
  To study the morphology, chemical and magnetic state of nanostructures with <10 nm resolution.

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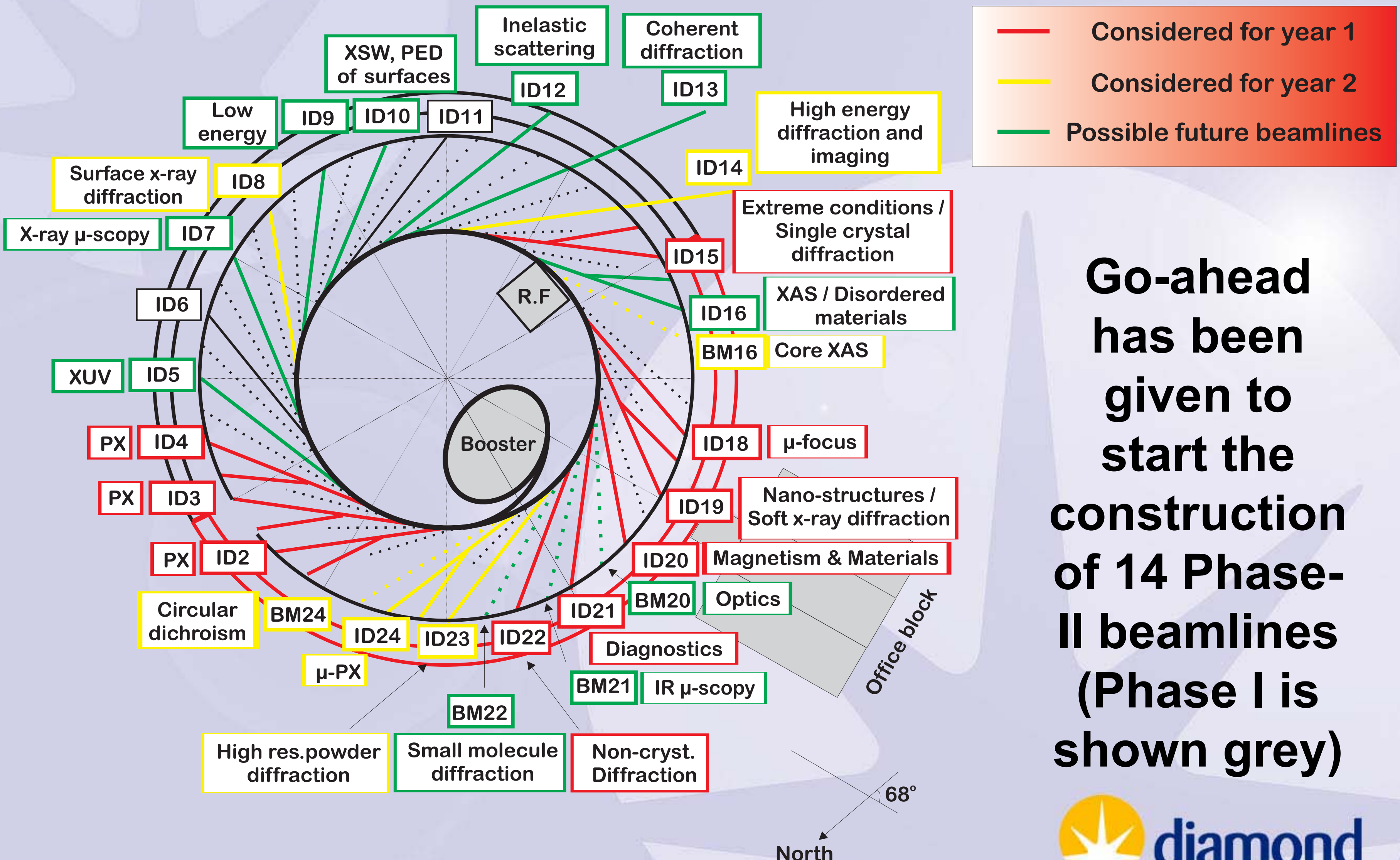
Beamlines



Go-ahead has been given to start the construction of 14 Phase-II beamlines (Phase I is shown grey)

diamond

V. Master Schedule and Status

Appoint Main Building Contractor	Jan. ’03	✓
Ground breaking	Mar. ’03	✓
Start main building works	Oct. ’03	✓
Start machine installation	Sep ’04	
Start beamlines installation	Jan. ’05	
Linac commissioning	May – Jul. ’05	
Booster commissioning	Sep. – Nov. ’05	
Storage ring commissioning	Jan. – Dec. ’06	
Beamlines commissioning	May – Dec. ‘06	
Start of User Operations	Jan. ’07	

Nov. 7th 2003

diamond

Jan. 29th 2004

Mar. 26th 2004

May 2^{nd} 2004

VI. Building/Conventional Construction

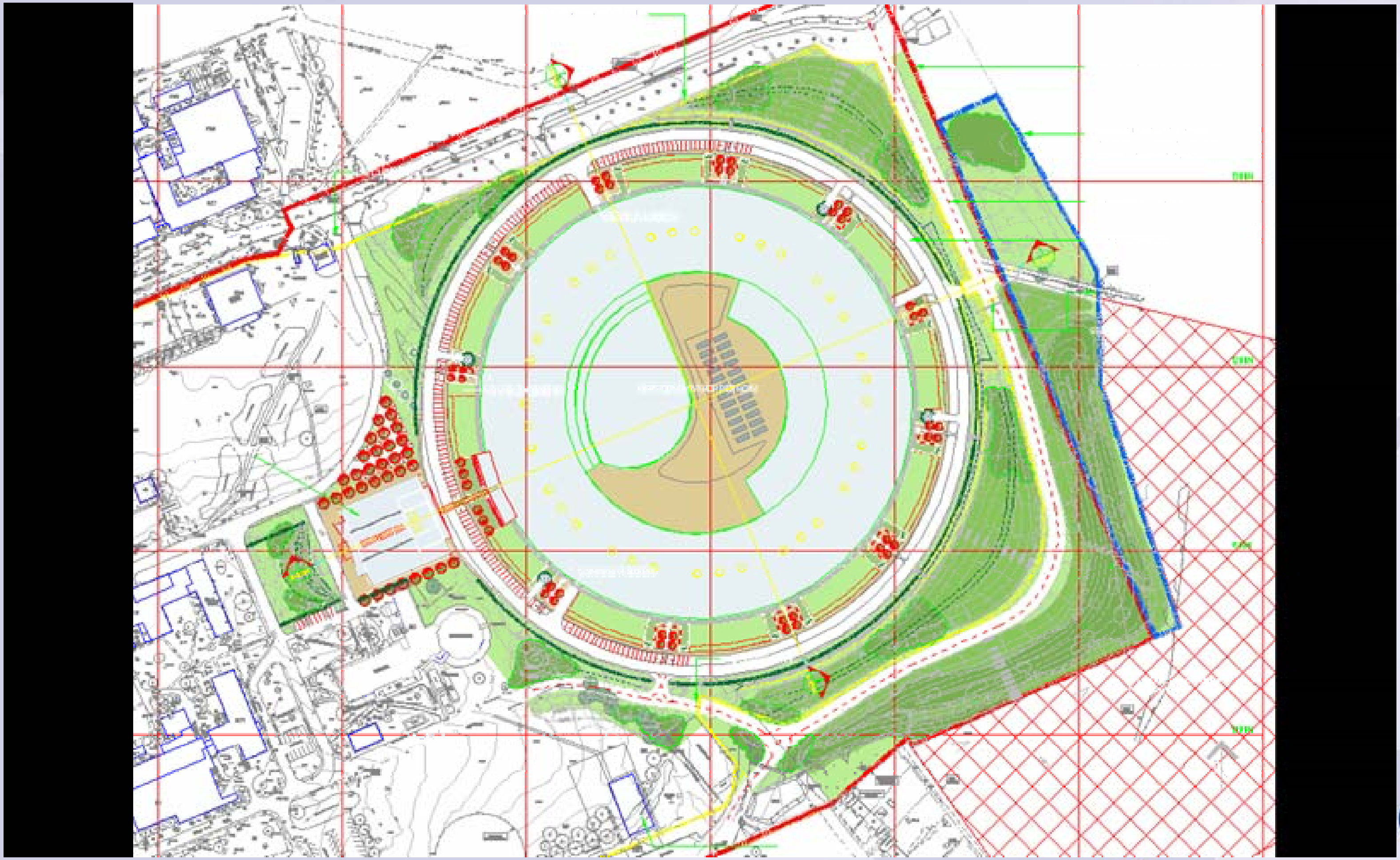
Keyed Roof Shielding

Engineering Building on Left
Walkway Not Yet Constructed

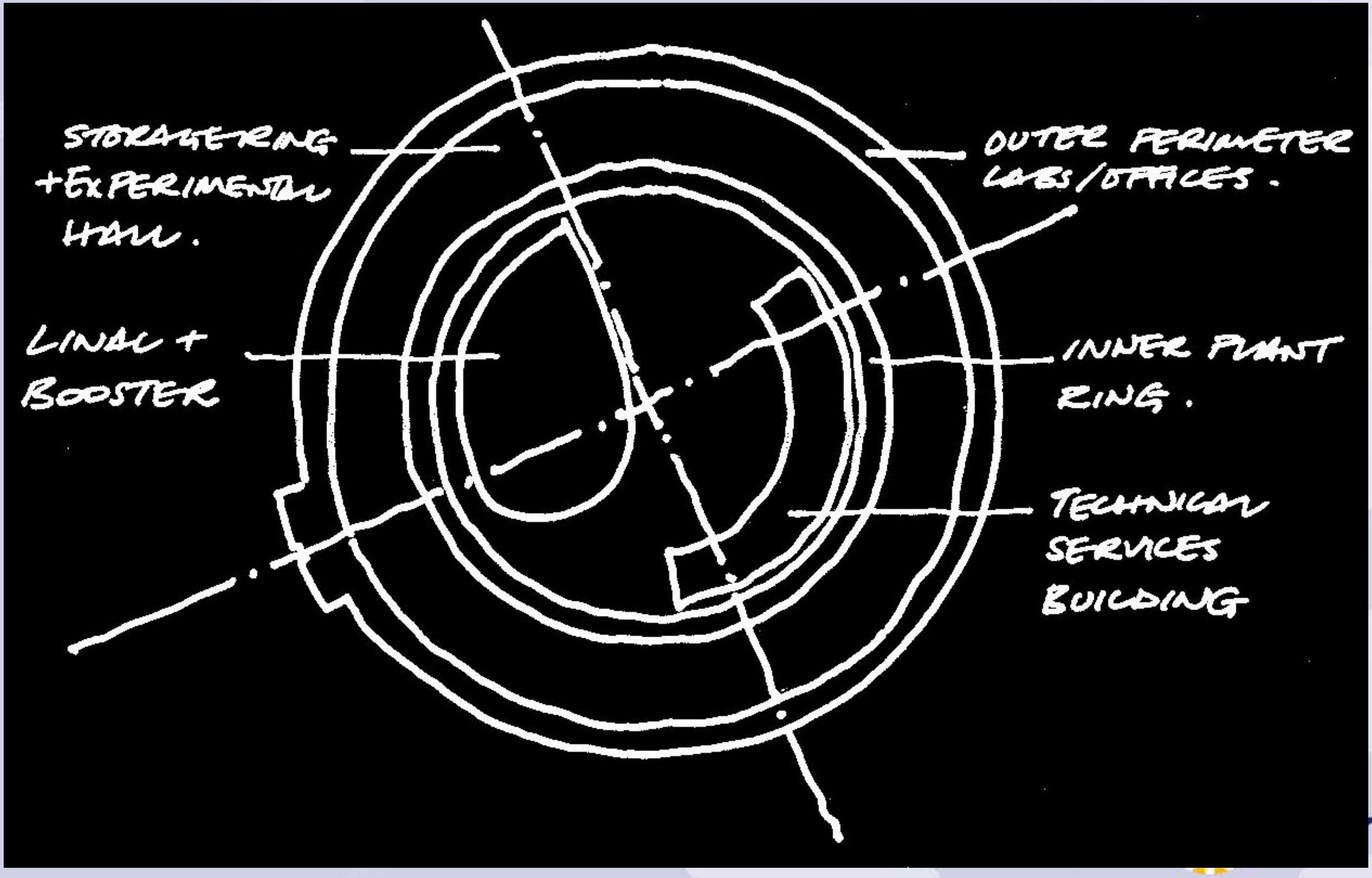
Building Design Criteria

235m diameter synchrotron + expansion zone + ring road and parking

Bridge to 5500m2 office block + drainage to soakage ponds



•Majority of plant in TSB-boiler, chillers, compressors, pumps etc
•Air blast coolers in courtyard.
•Other plant in inner plant ring and by laboratories.
•No bridge over or under ring- center access by 20T internal crane only



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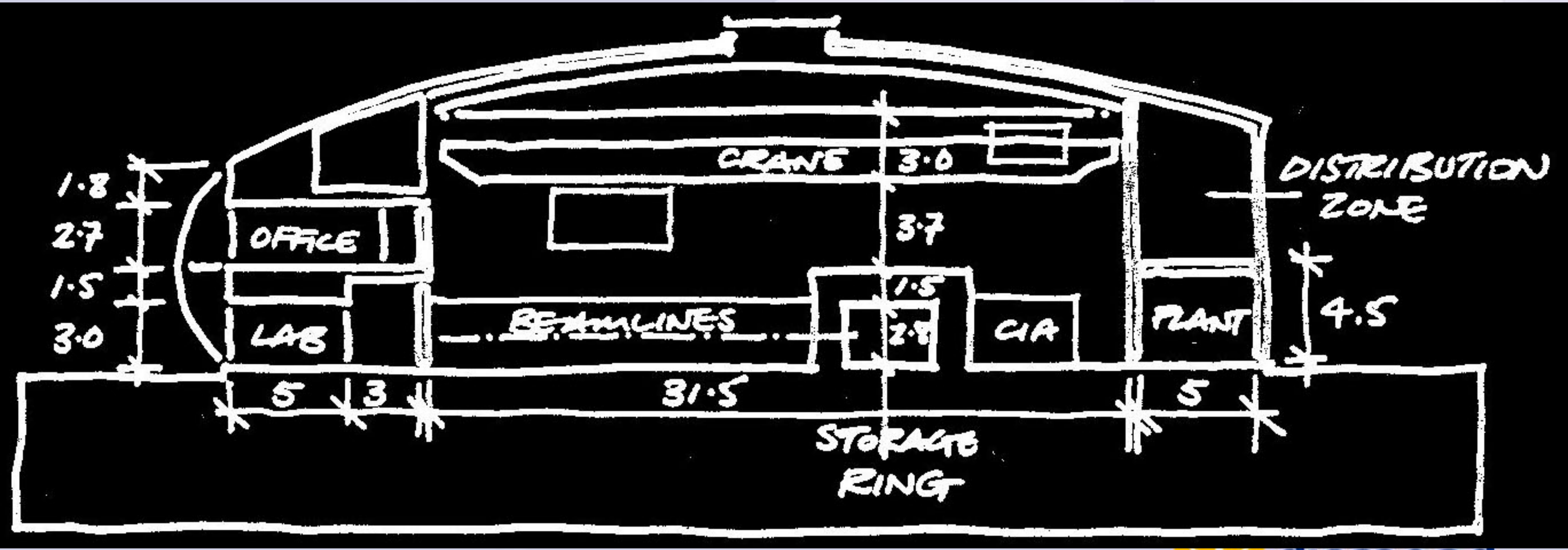
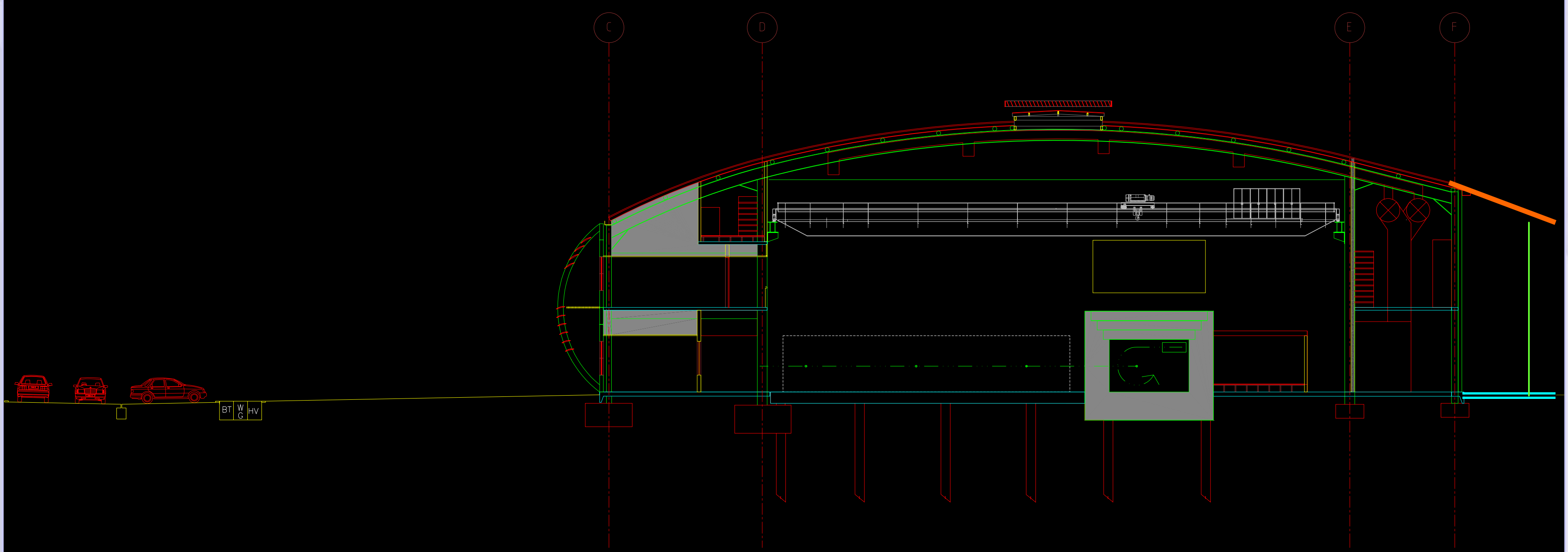
- Three 20T cranes
- Service distribution in inner and outer service zones
- 12 Sectors served by staircases – 2 mtls lifts, 5 passenger lifts
- Natural light into experimental hall (expansion/contraction issues?)
- 2 link bridges across experimental hall.
- Accelerator vault has removable concrete roof panels (ref. ESRF)

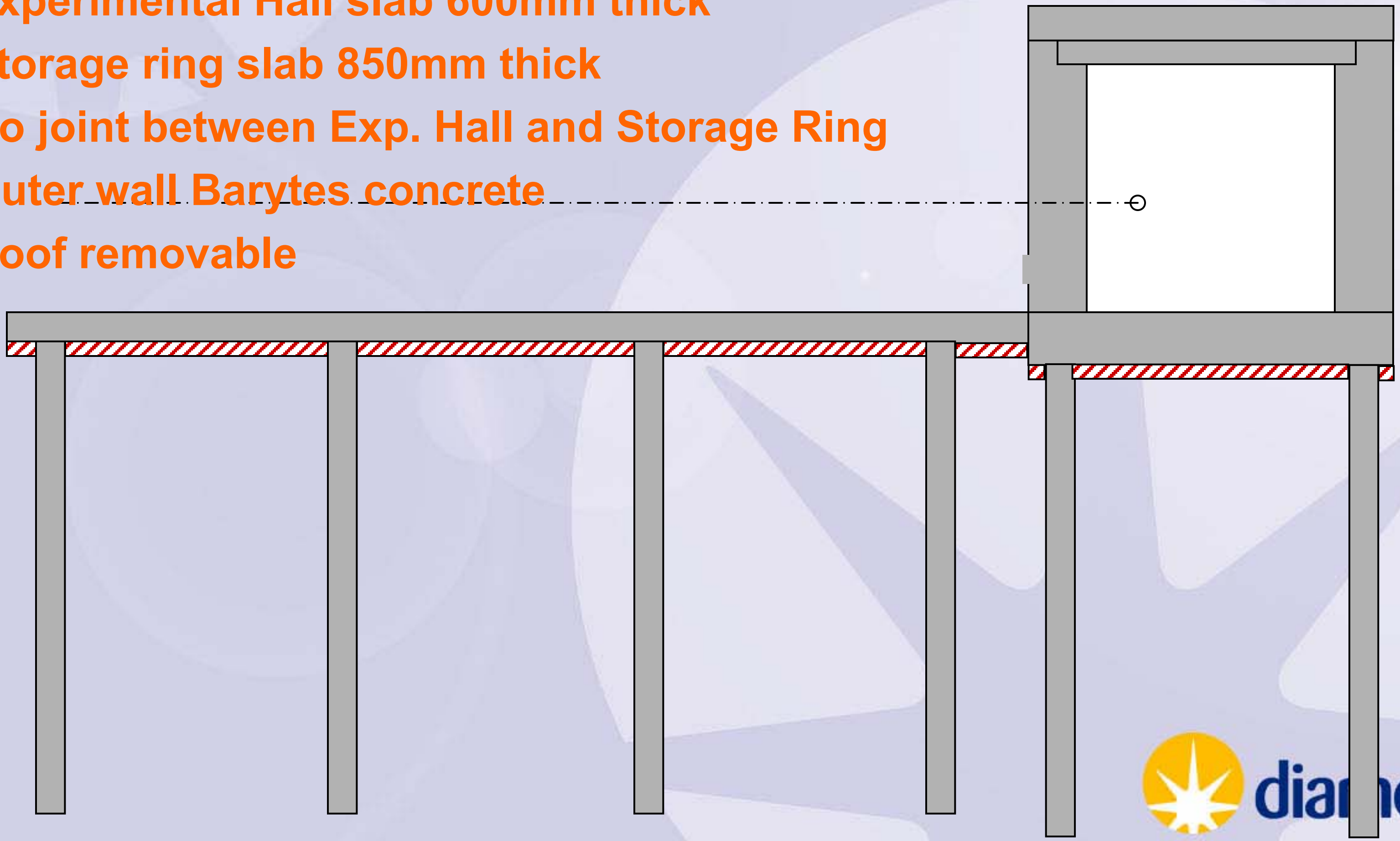


Service Routes + Smoke Extract + Foundations



Tunnel & Exp'l floor foundation

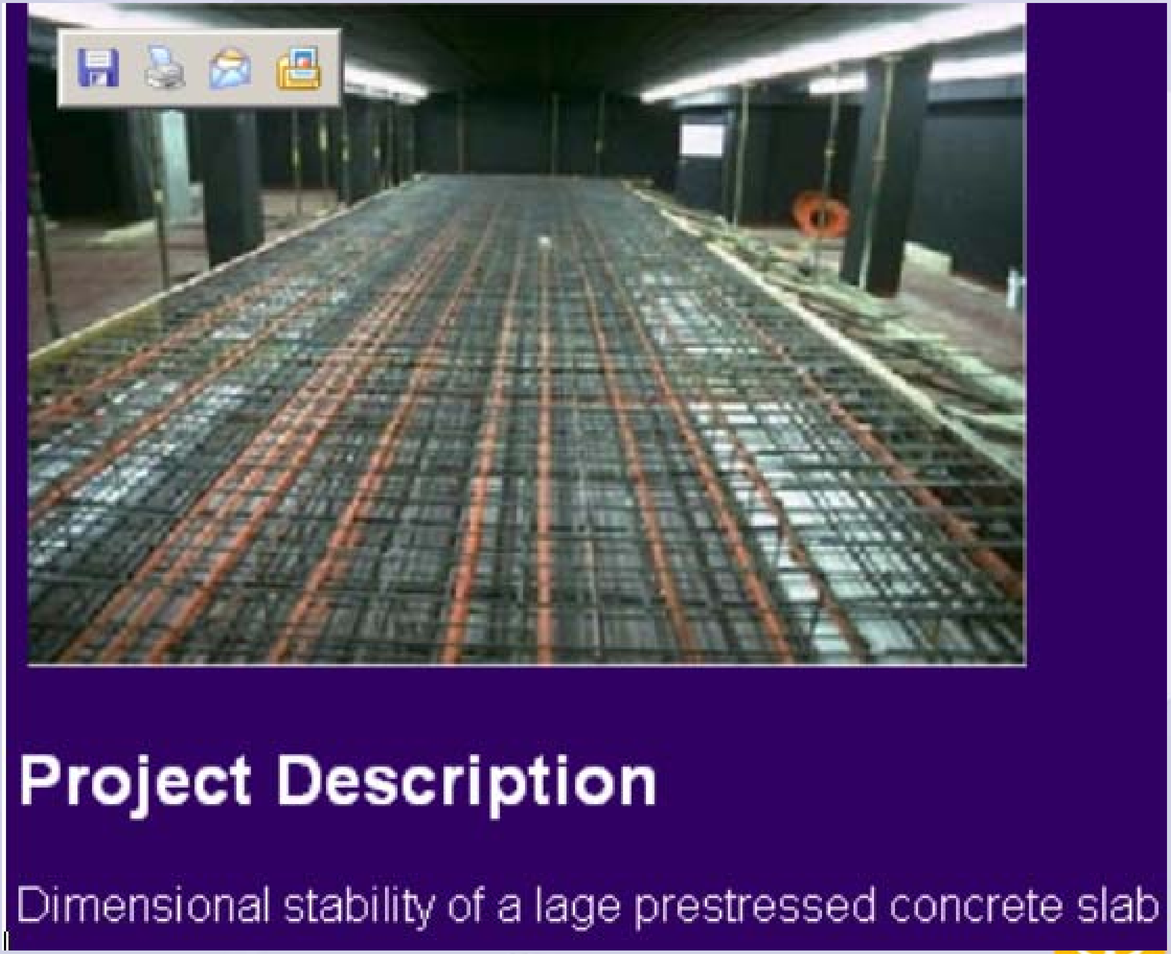
- Non sleeved piles 12 to 15m long .
- Designed gap under all piled slabs
- Piles at 3 m grid under Experimental Hall
- Experimental Hall slab 600mm thick
- Storage ring slab 850mm thick
- No joint between Exp. Hall and Storage Ring
- Outer wall Barytes concrete
- Roof removable



-10 personnel safety zones with internal gates, searches progress quickly

-Heavy concrete in ratchet wall, normal concrete in between

Diamond-concrete-slab-test



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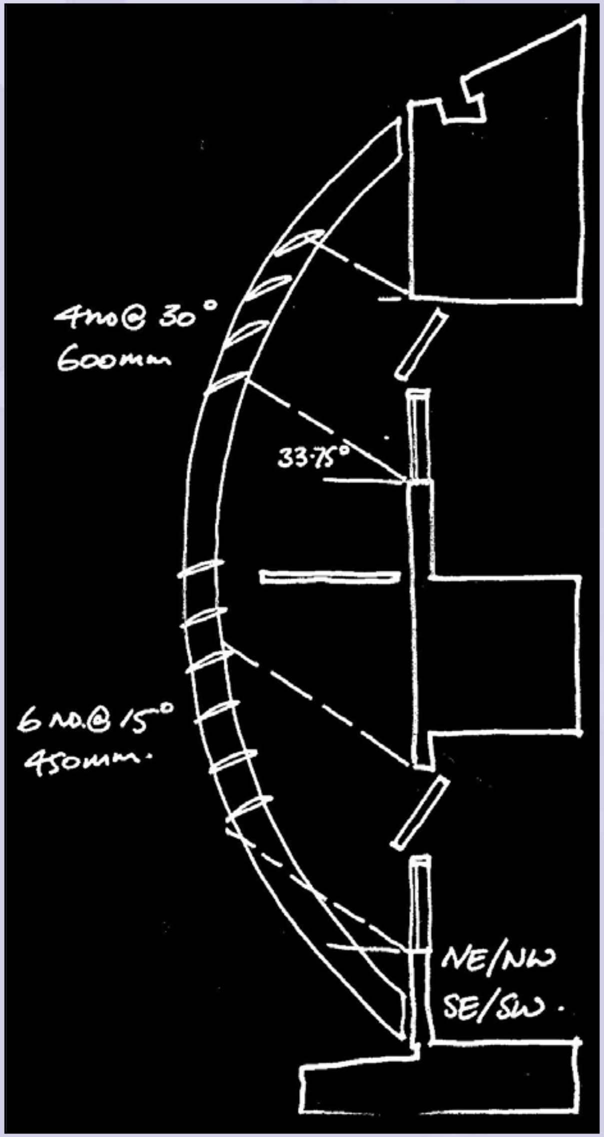
Diamond-floor-lining-thermal-test



- External walls are a series of straights rather than curves on cost grounds.
- External louvres for solar shading
- Opening windows for natural ventilation

Building Services

Air Conditioning:

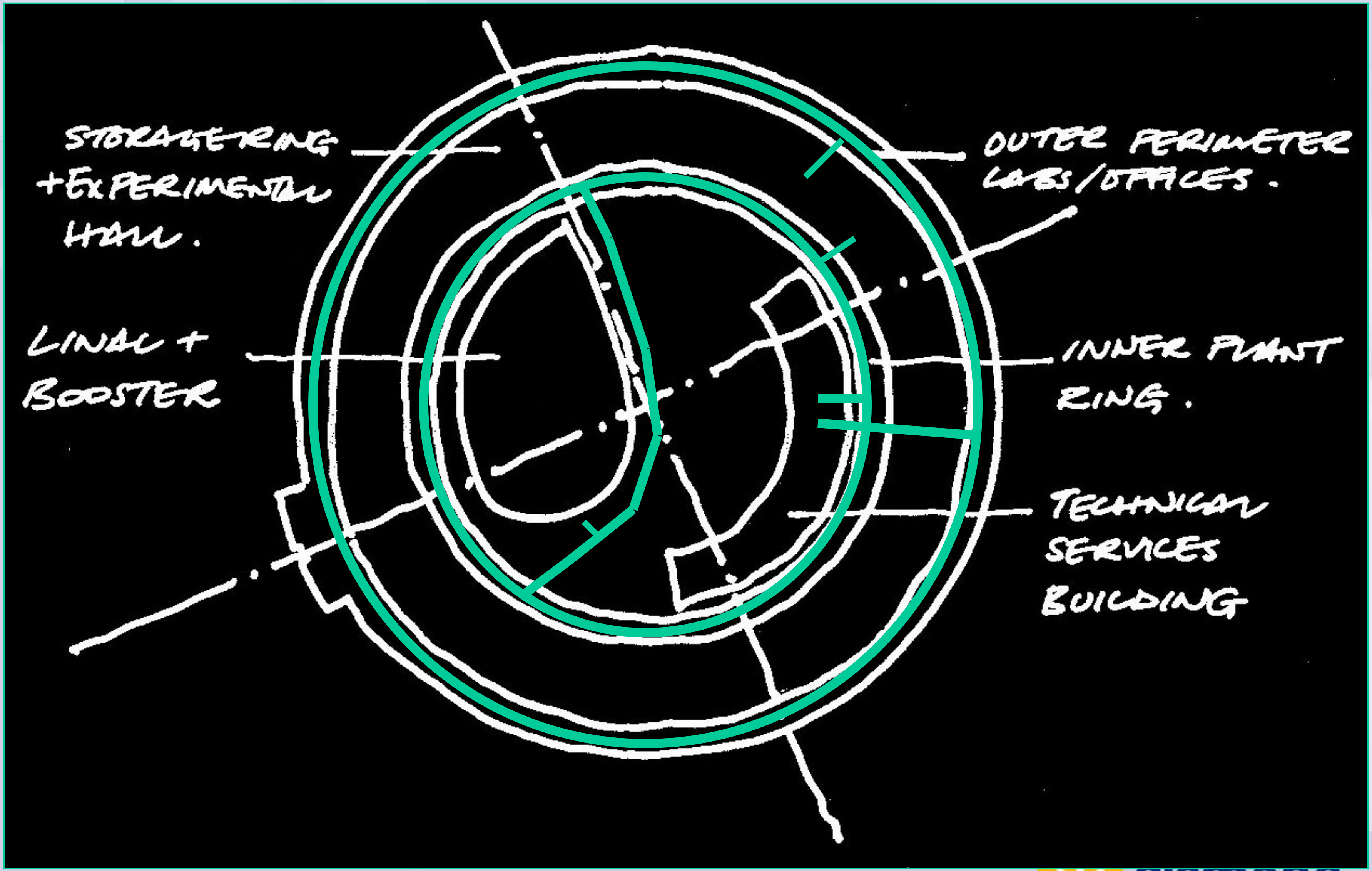
Experimental Hall controlled to +/- 1 Deg C
Tunnels controlled to +/- 0.5 Deg C
CIA's have constant air temperature to racks of 16 Deg C
Labs and Offices natural ventilation.

Process Water:

Demin, Raw and separate circuit for Aluminium equipment. Pressure and temperature varies with point of use. Supplies stop at entrance to labyrinths.
Load in process water 5.8MW. No heating on systems.

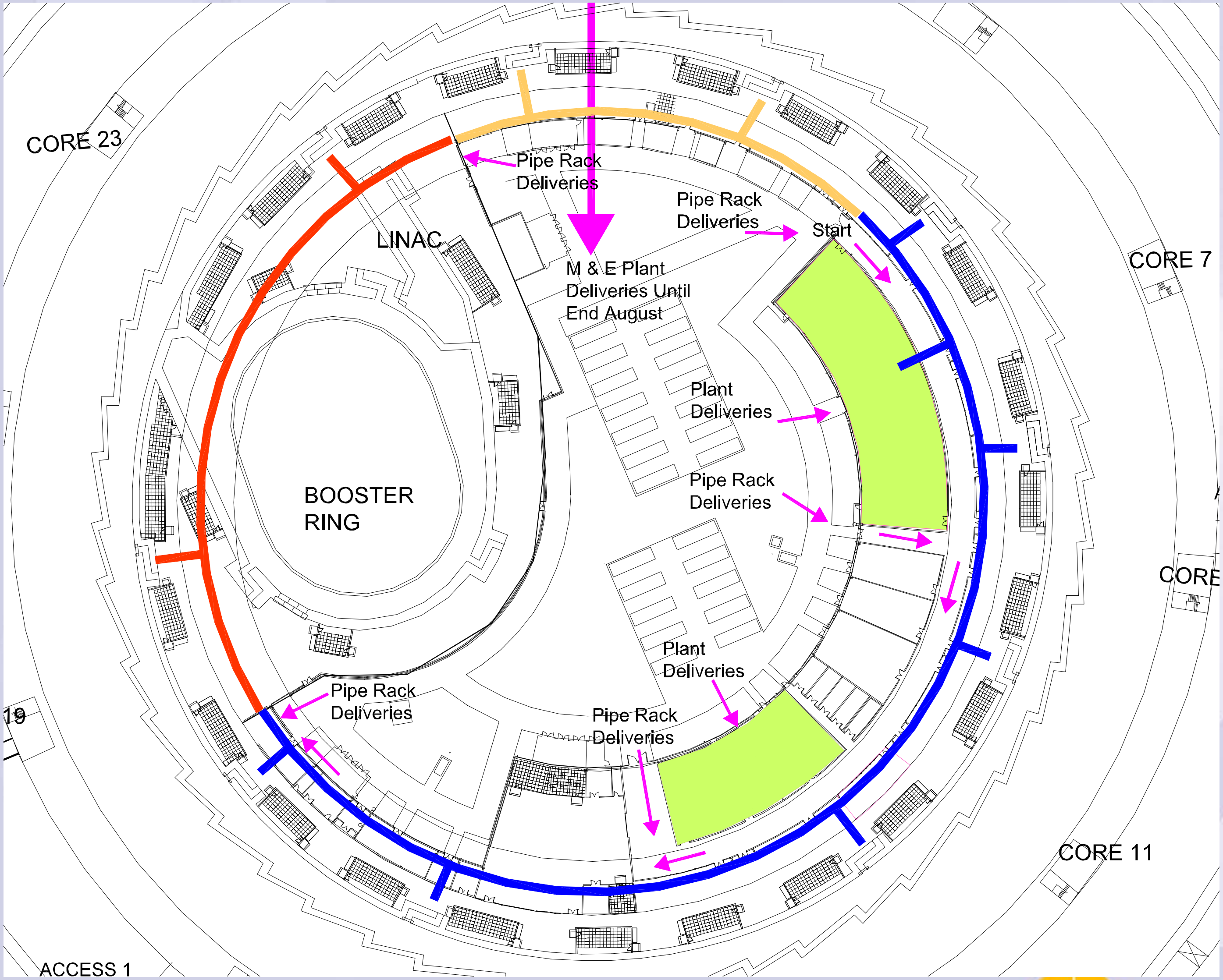
Liquid Nitrogen:

Ring main in outer service corridor feeding beamlines from 4 external tanks. Capacity only for two simultaneous users per quadrant.



STORAGE RING
+ EXPERIMENTAL
HALL.
LINAC +
BOOSTER
OUTER PERIMETER
LABS/OFFICES.
INNER PLANT
RING.
TECHNICAL
SERVICES
BUILDING

Process water to storage ring



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Power Supplies

- 11 kV from site main substation into TSB main sub.
- 11 kV from TSB sub to distributed subs
- Local distribution at 400 V

- UPS supplies limited to CIA's and Control room.
- Generator for control room supplies.

- No on-site power generation.

- Total facility load 18MVA

Other systems:

- Oil free compressed air to labyrinths and end of beamlines.
- No gaseous nitrogen
- No piped helium
- Vacuum fume extract ring in outer service corridor
- Vacuum liquid extract from beamlines
- Cat 6 Data system
- Smoke detection, voice alarm/PA, smoke curtains and fans.
- Heating in offices and labs

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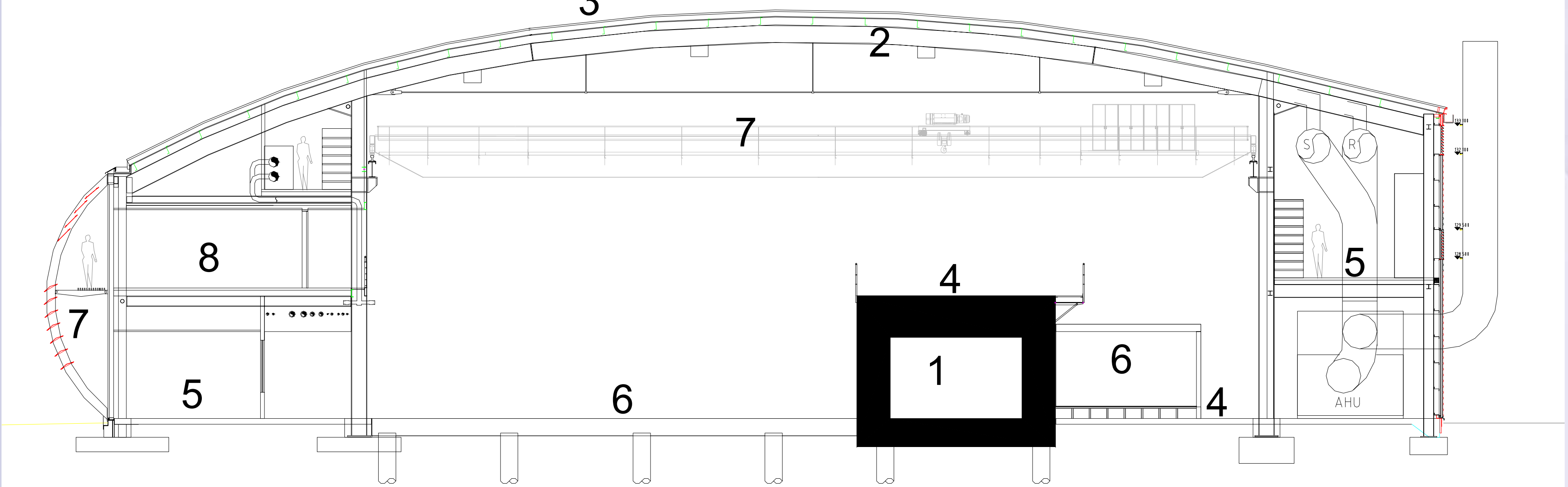
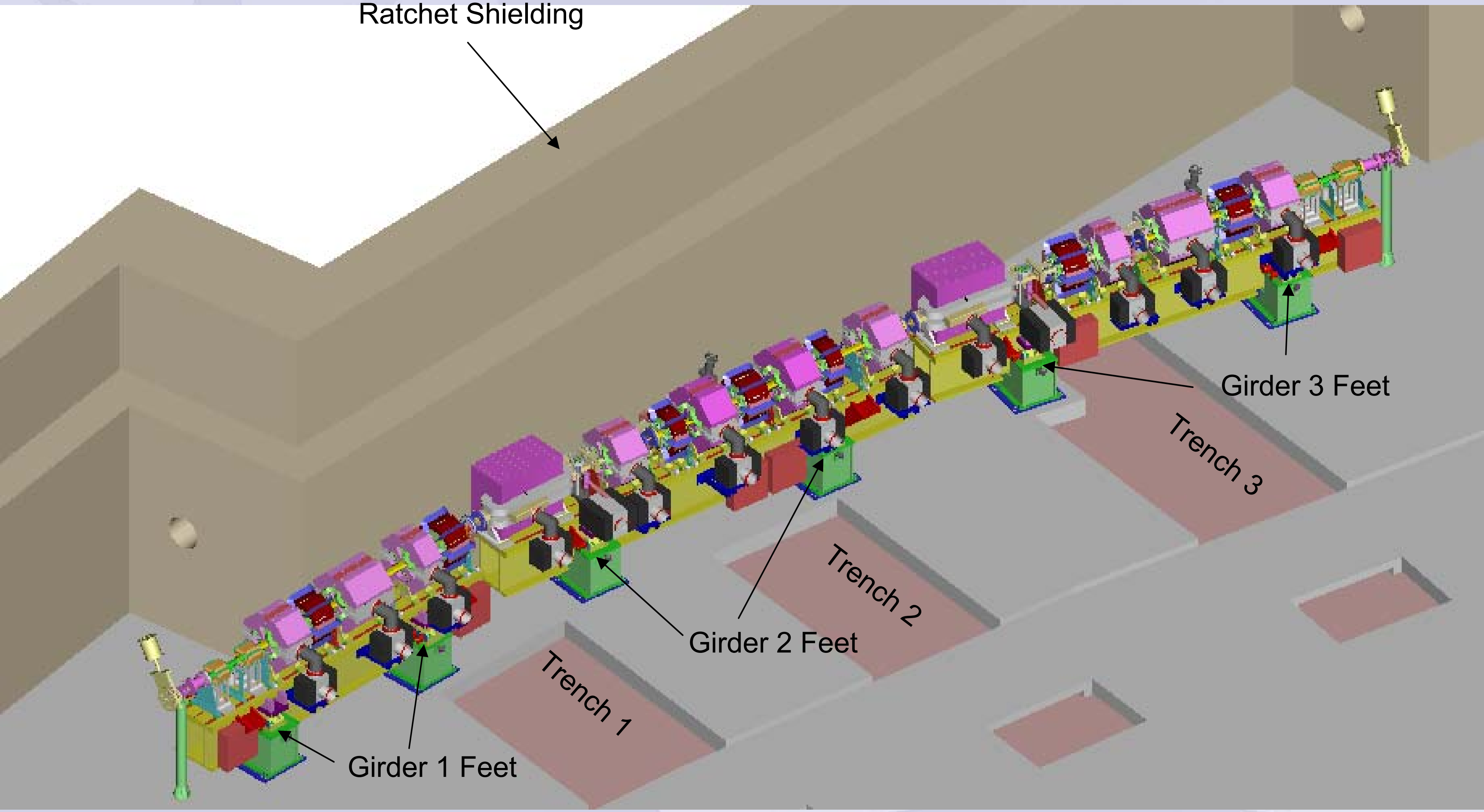
Construction Sequence

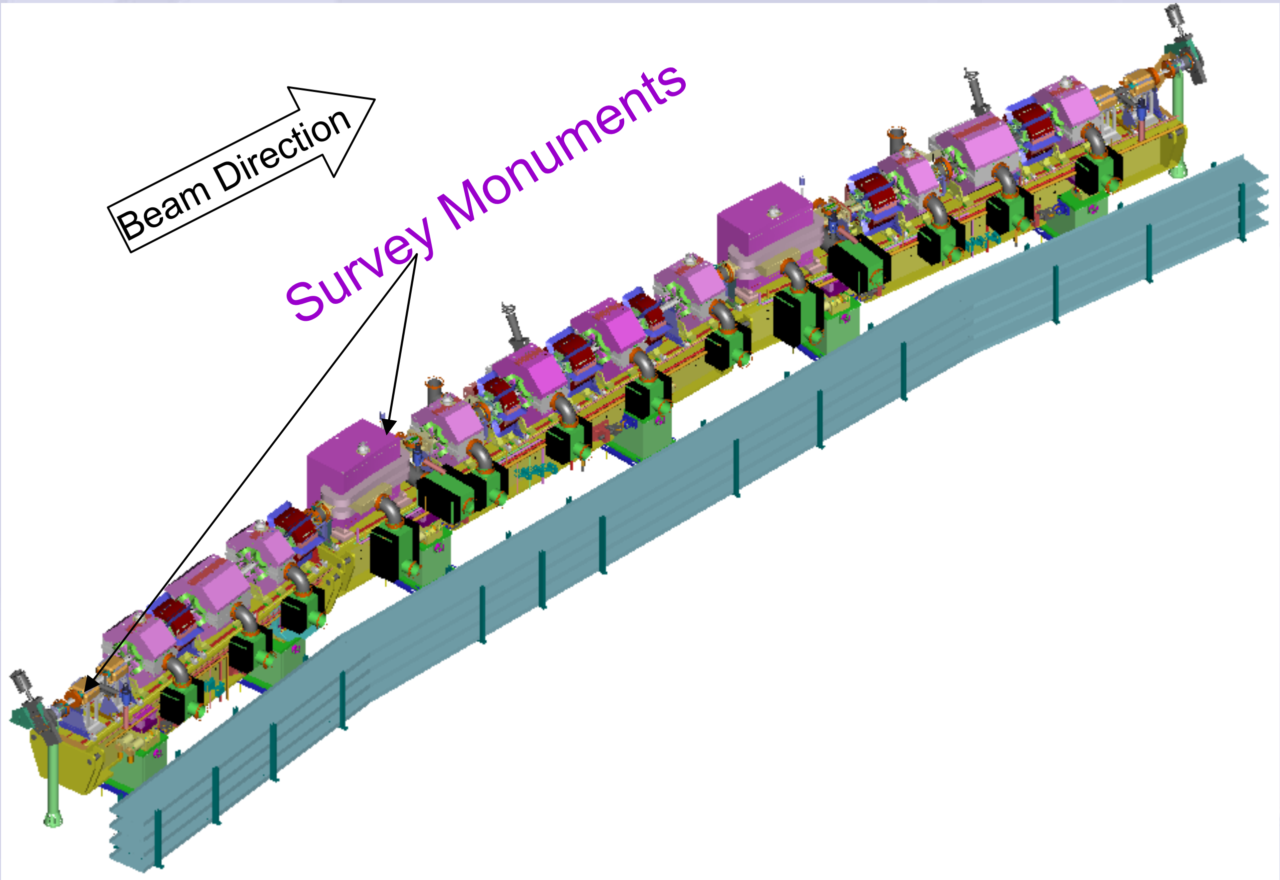


VII. Storage Ring Mechanical Design

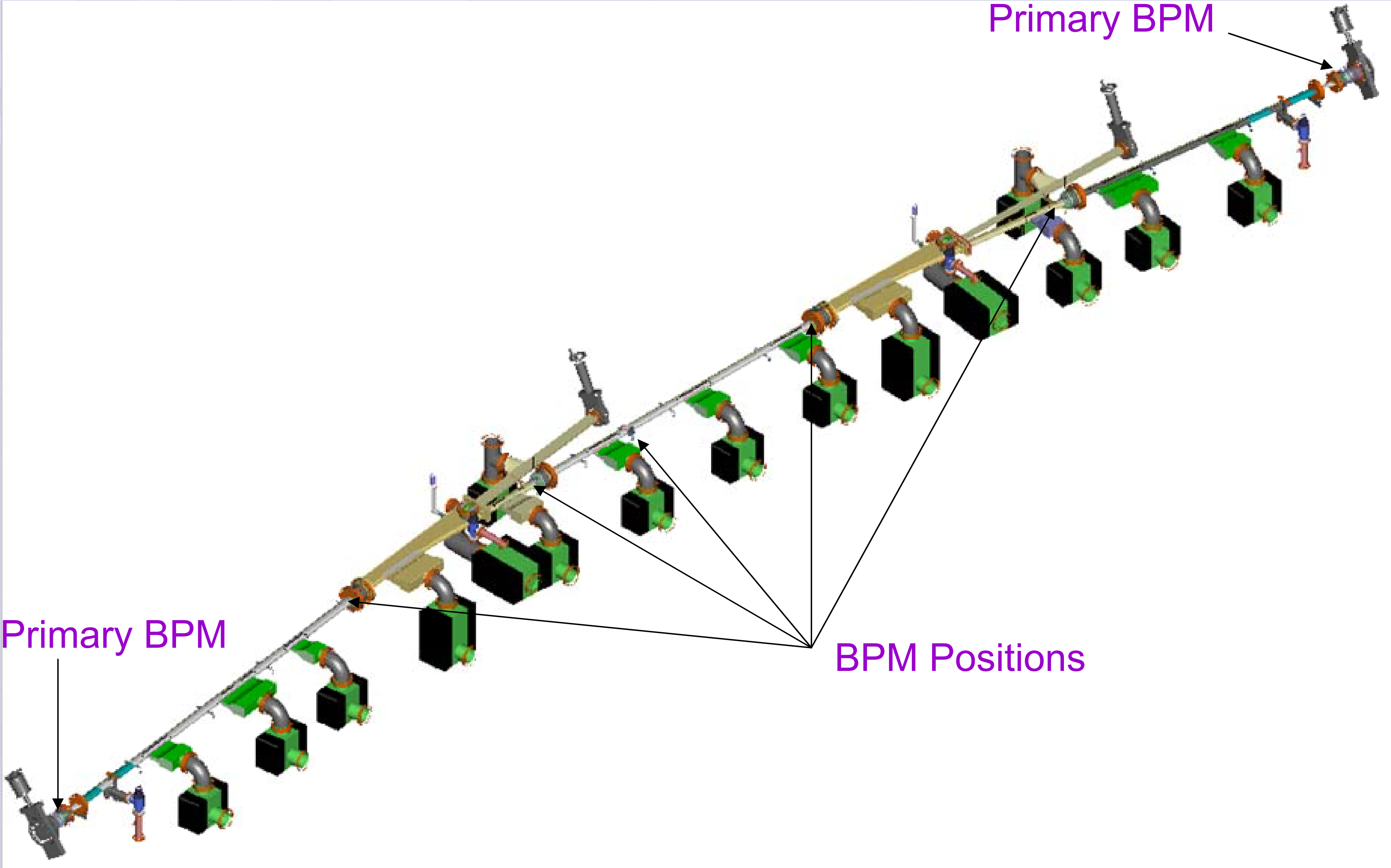


SR Three Girder Configuration

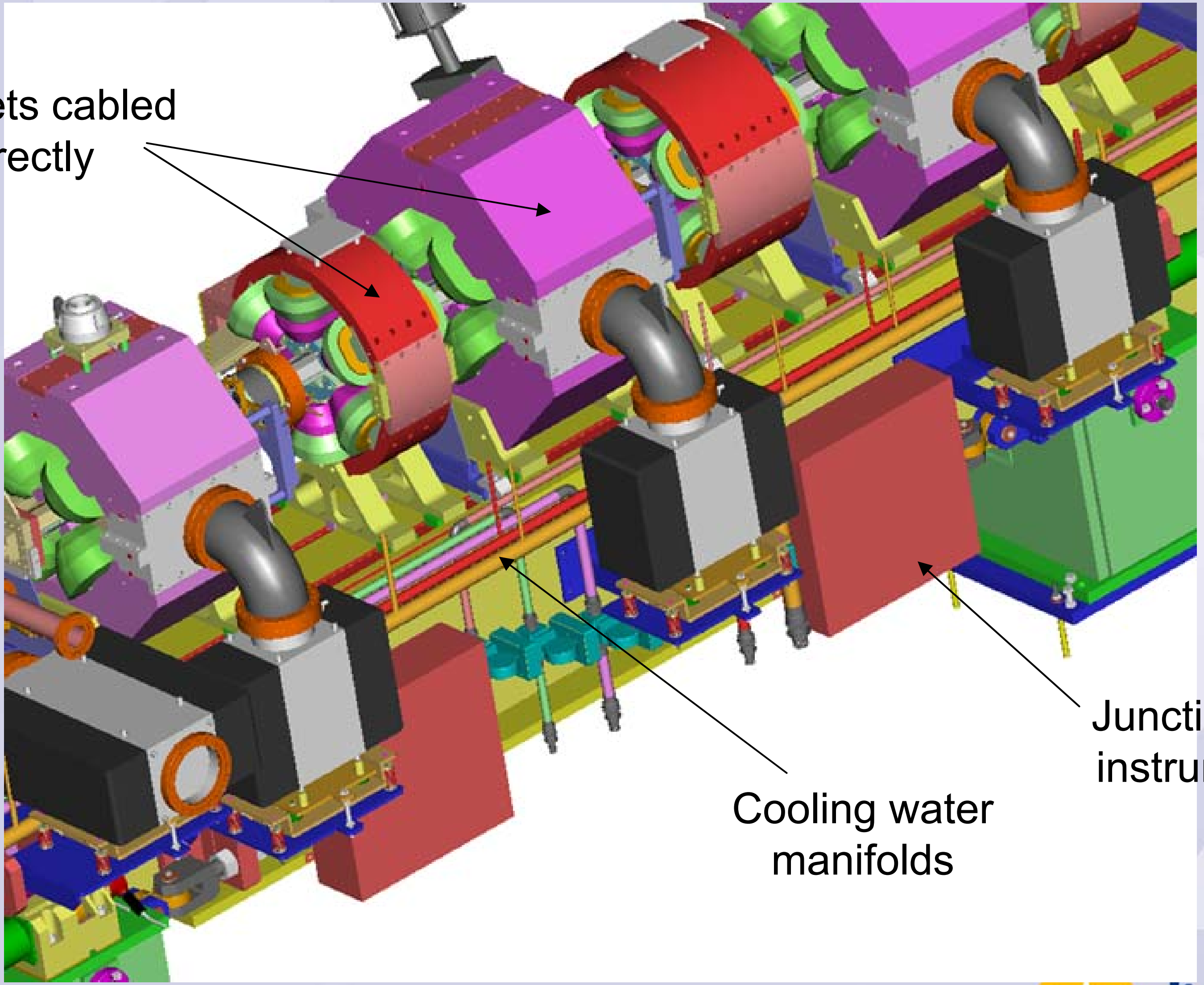
DBA Superperiod



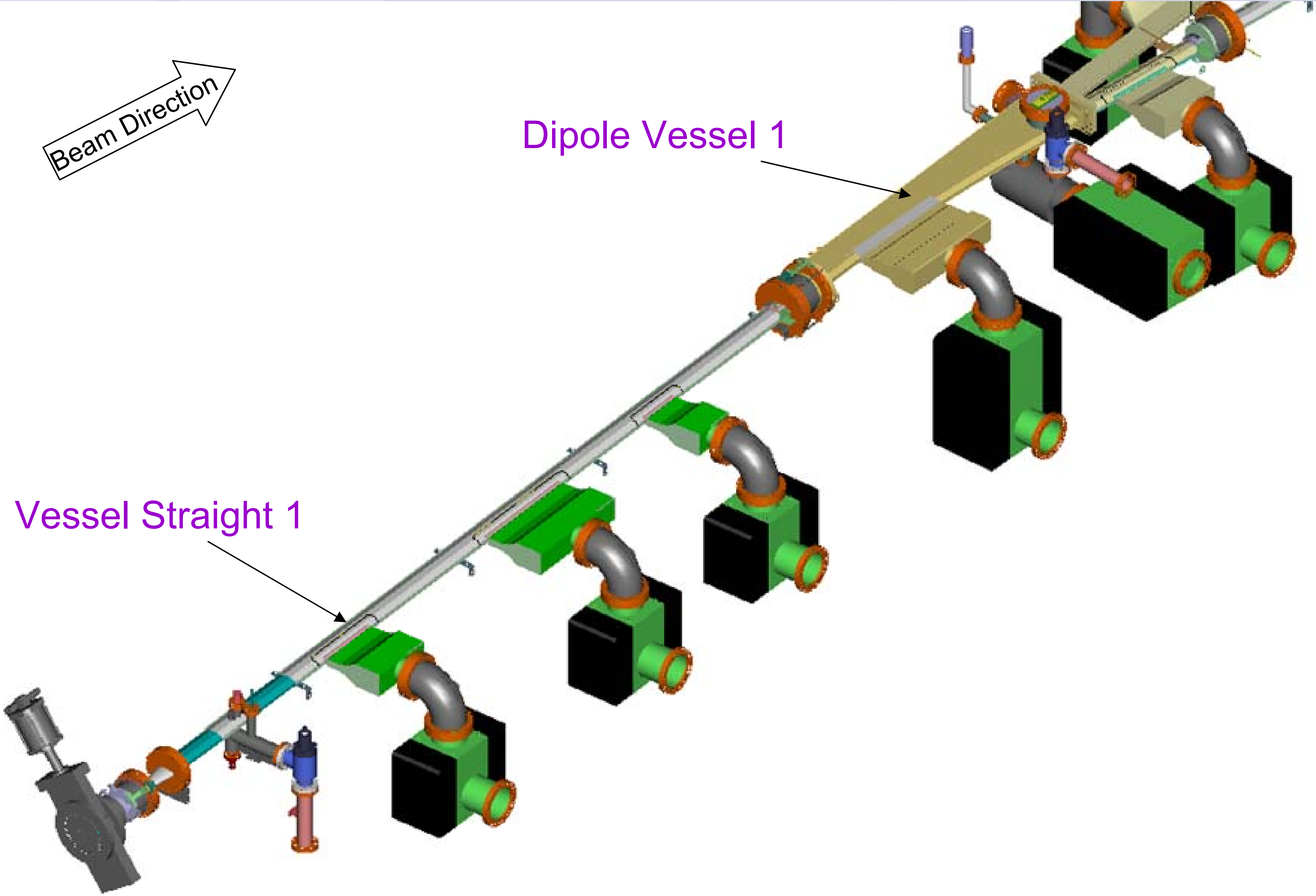
Vacuum Chamber

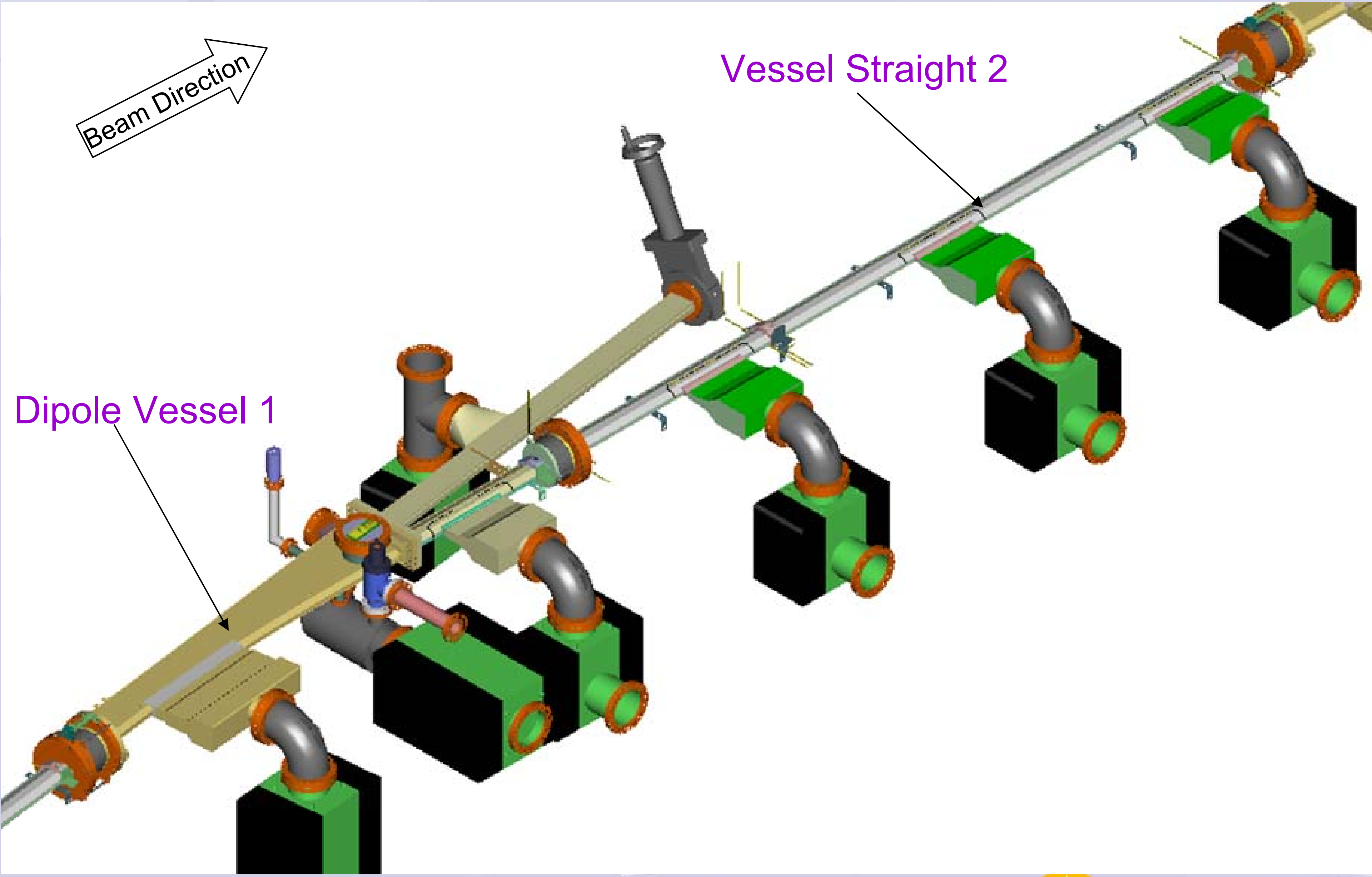


Manifolds and Junction Boxes on Girders

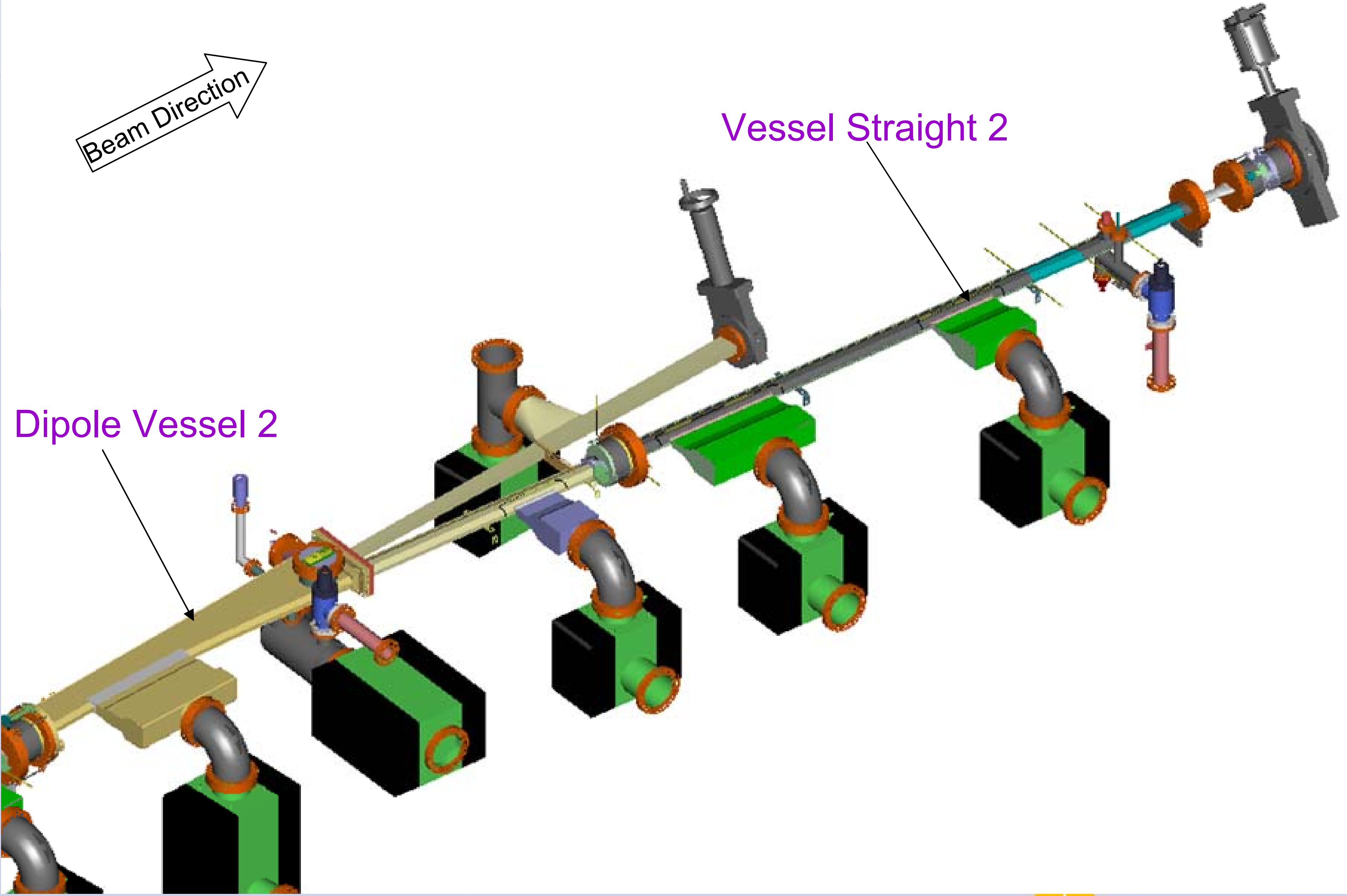


Note arrangement of magnets, pumps & services on girder


Beam Direction
Dipole Vessel 1
Vessel Straight 1



Beam Direction
Vessel Straight 2
Dipole Vessel 1



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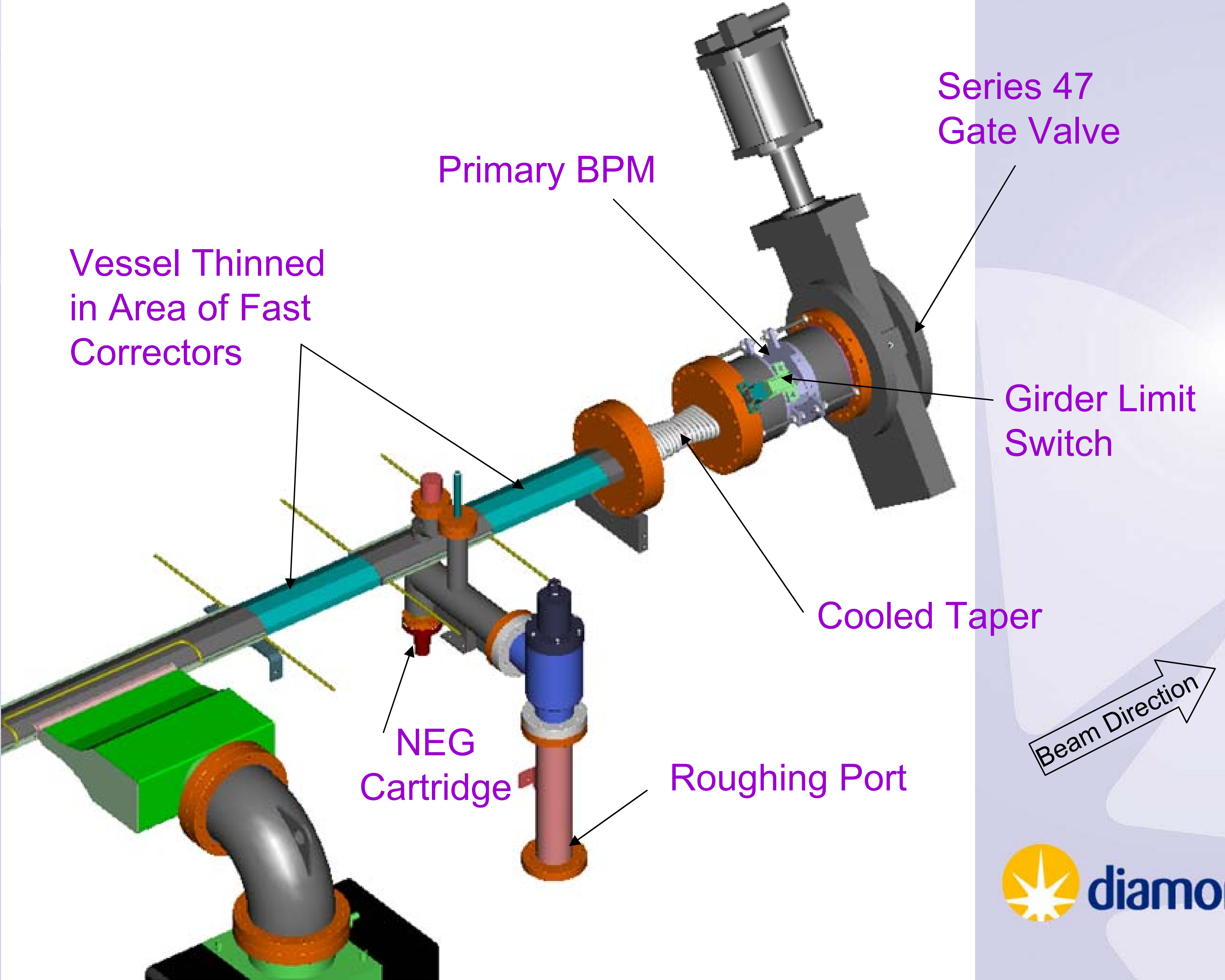
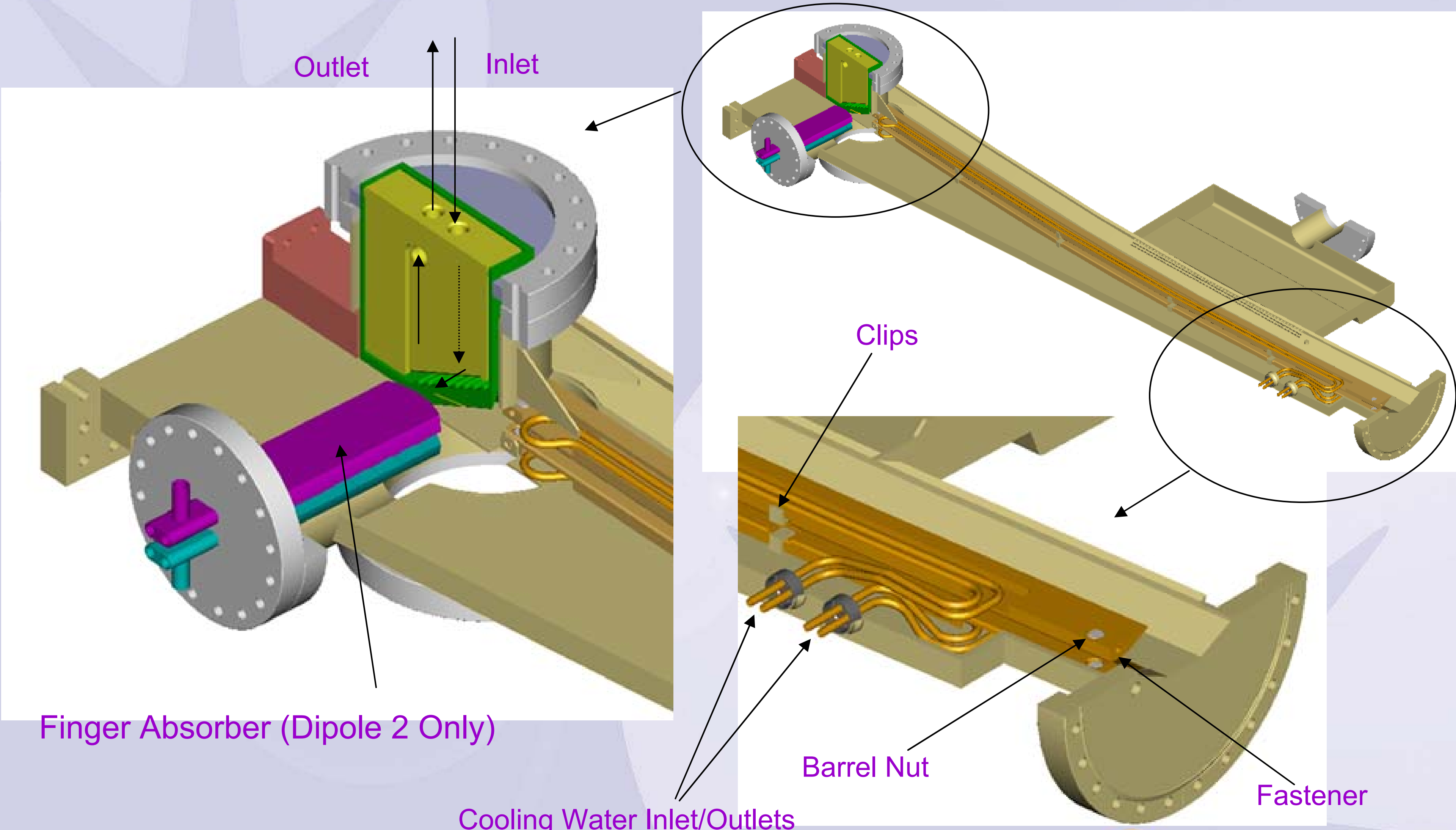

Series 47
Gate Valve
Primary BPM
Vessel Thinned
in Area of Fast
Correctors
Girder Limit
Switch
Cooled Taper
NEG
Cartridge
Roughing Port
Beam Direction

Sectioned Dipole Vessel - Showing Absorbers



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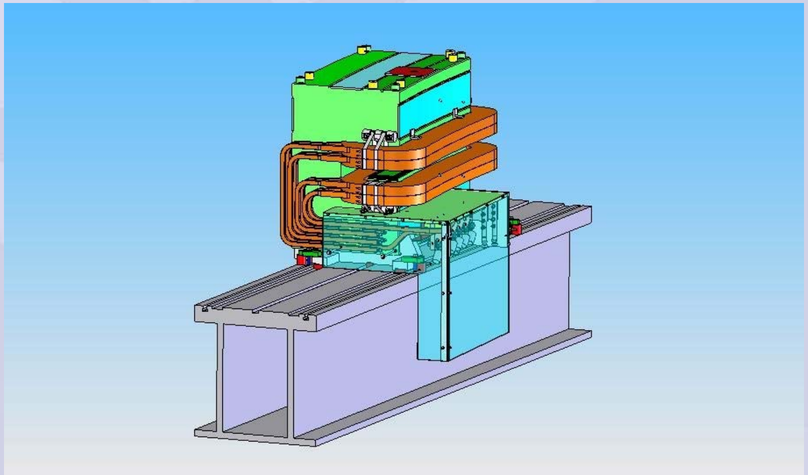
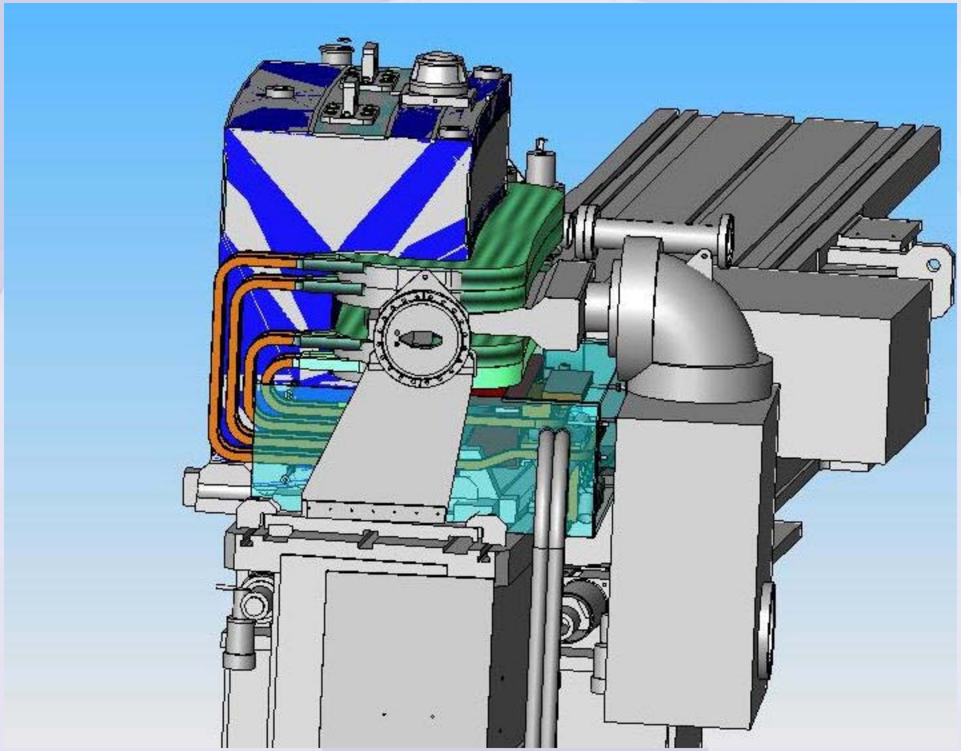
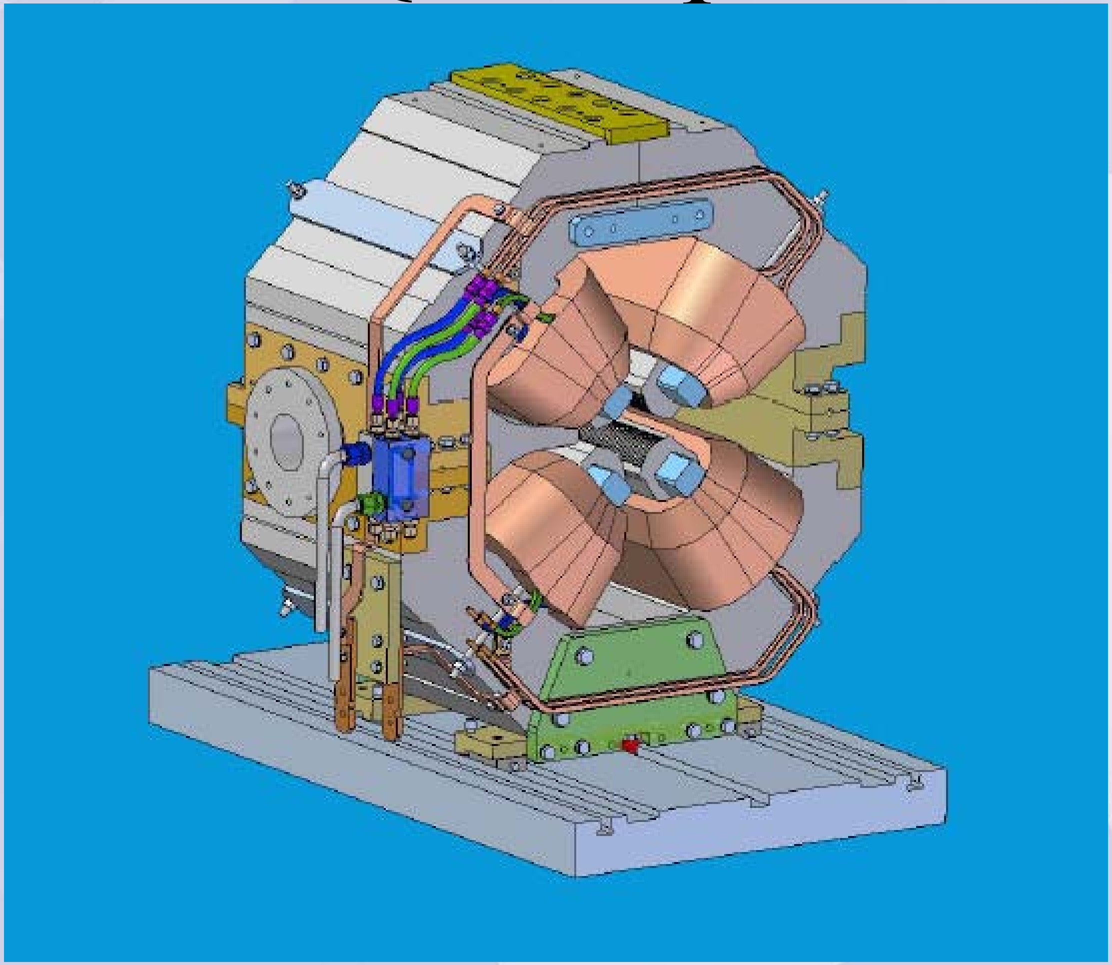
Dipole Magnet



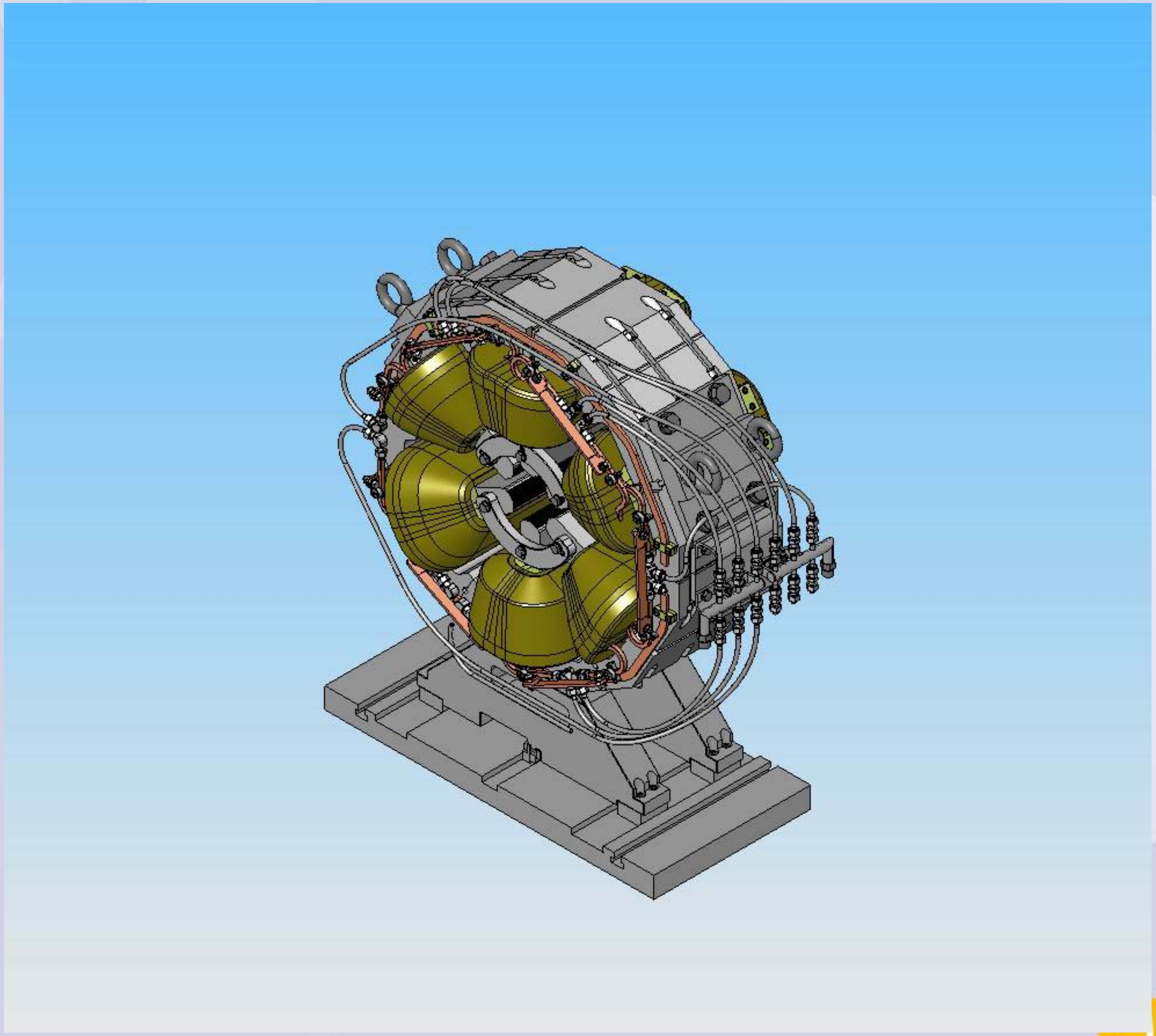


Quadrupole



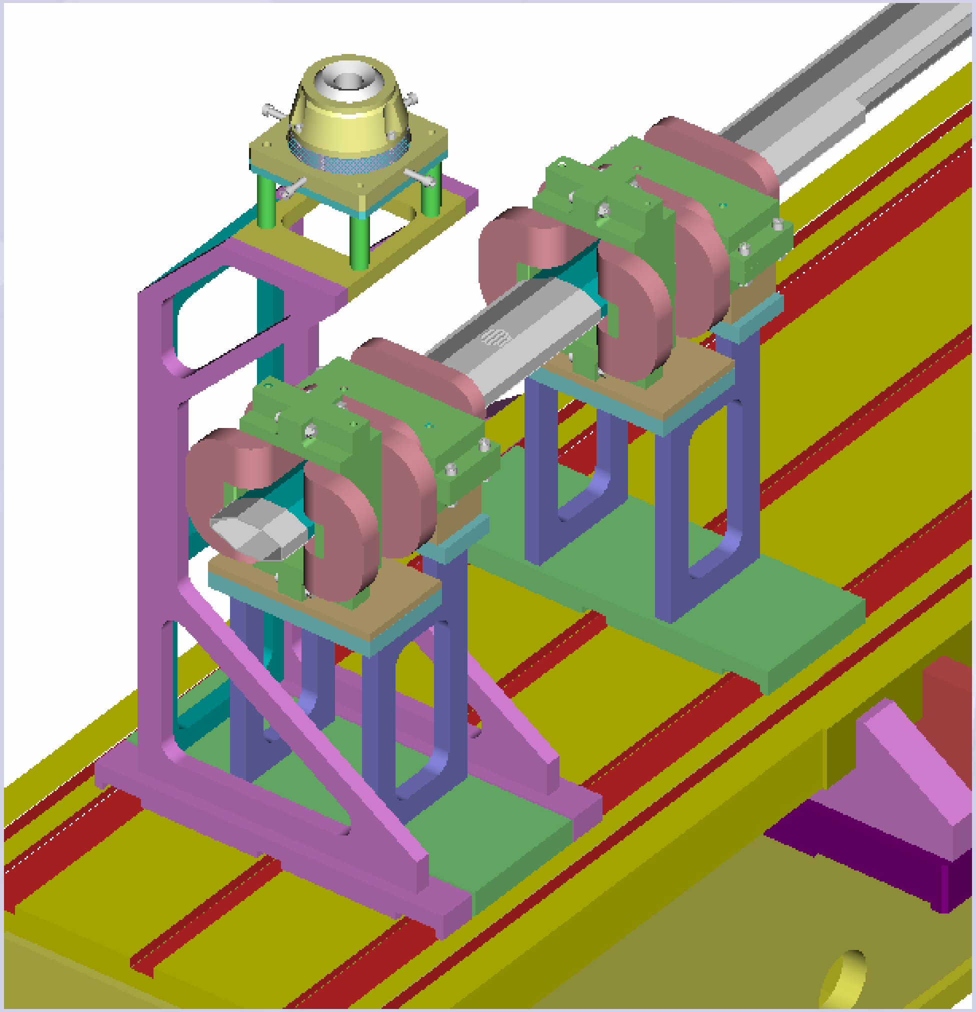
Note Quadrupole is located by girder grooves.

Sextupole



Note Sextupole is located by girder grooves.

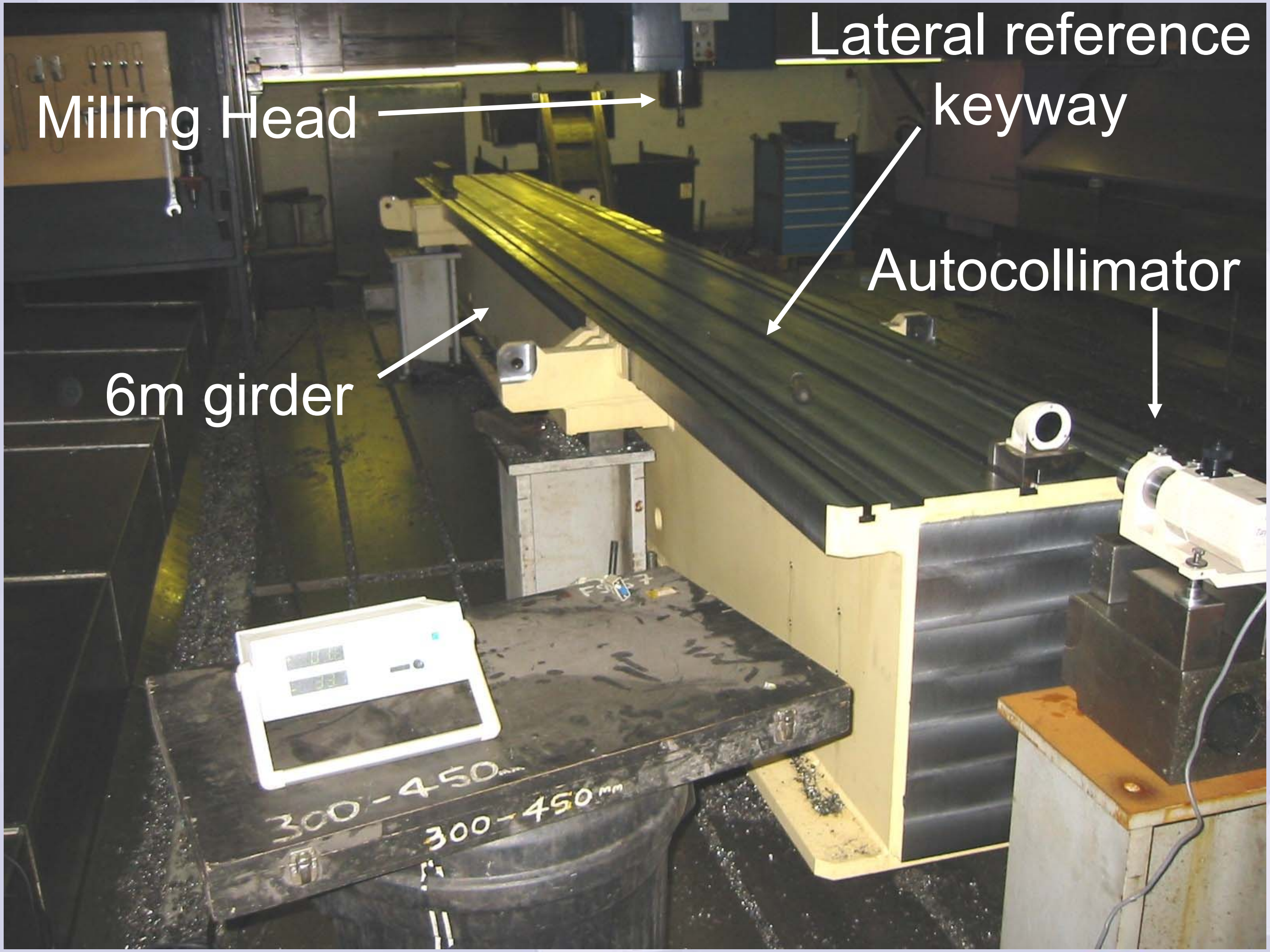
Fast Corrector Magnets



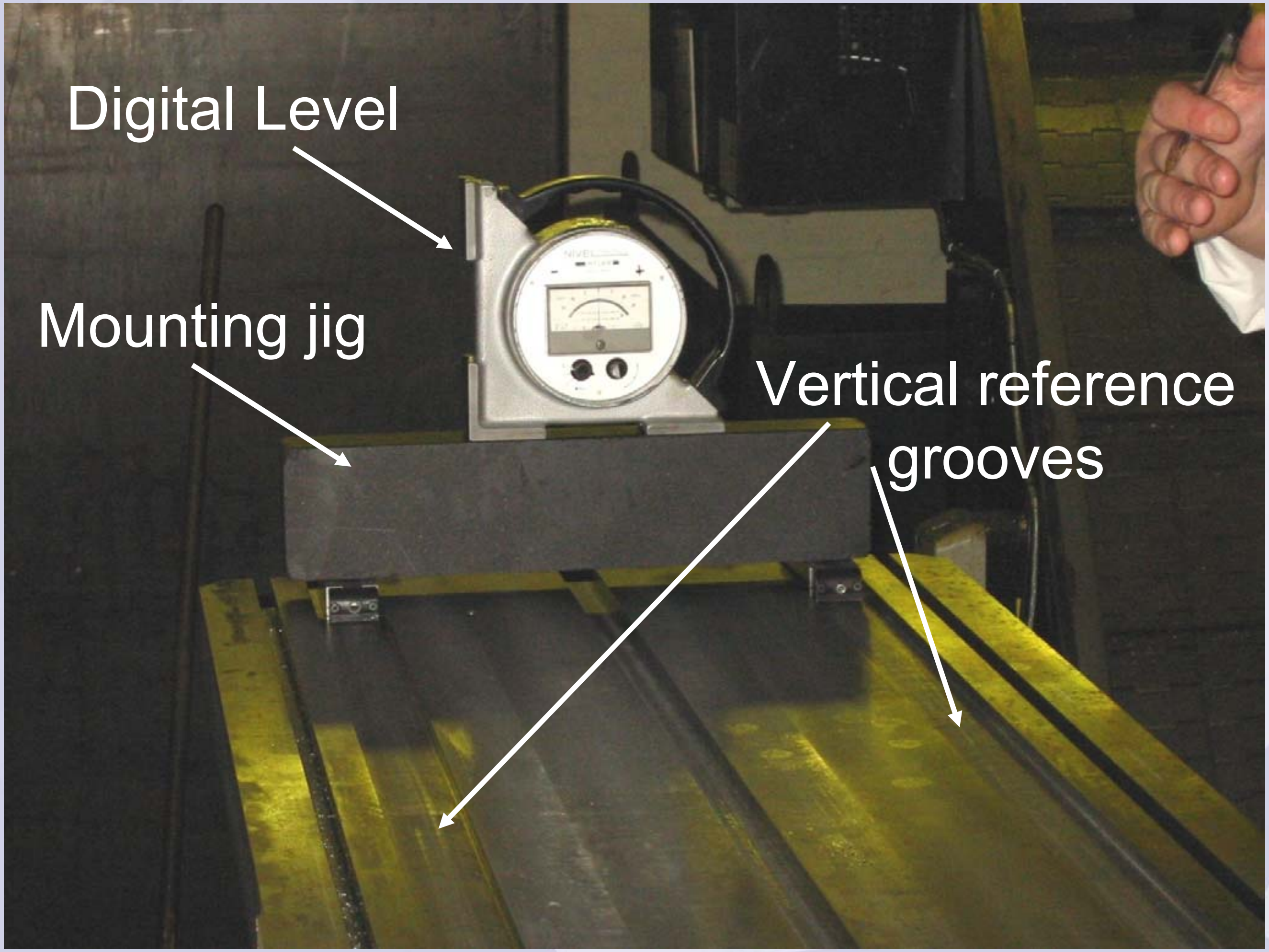
Fast correctors are also located by girder grooves.

Diamond girder

Machining precision locating groves into girder



Prototype Girder Inspection at the Manufacturer



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Straightness of Lateral Keyway Measured at Manufacturer for 6m Girder

Maximum peak to valley = 18.17μm

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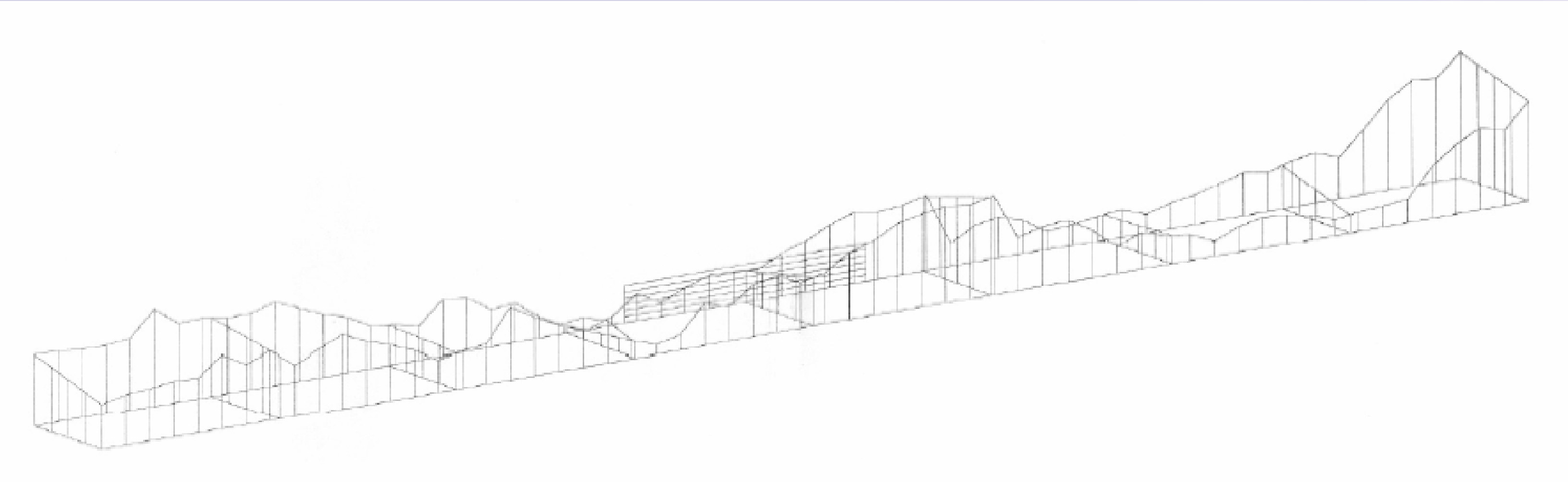
Roll between Vertical Reference faces Measured at Manufacturer for 6m Girder



Maximum peak to valley = 20.0μm

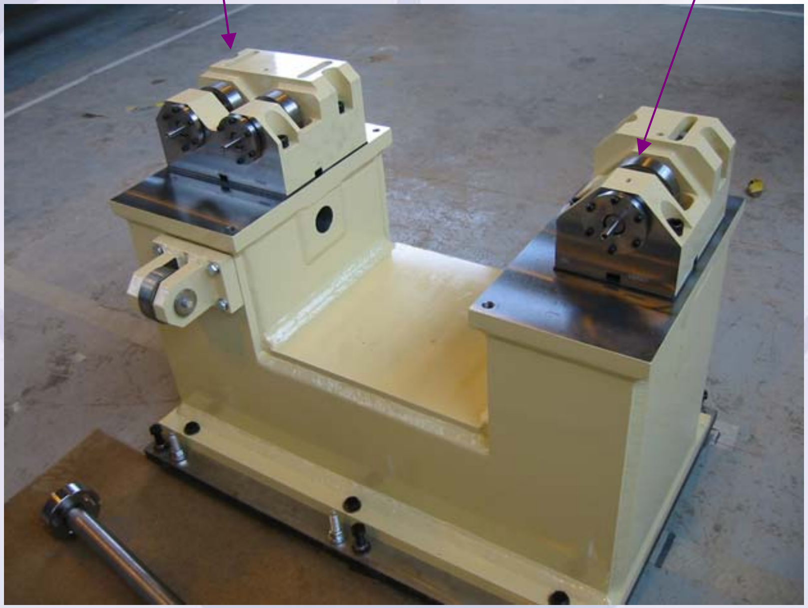
Equivalent to 0.05mrad roll

Delivery of Prototype Girder Positioners

‘Single V’ Rollers

‘Double V’ rollers

‘Flat’ Roller



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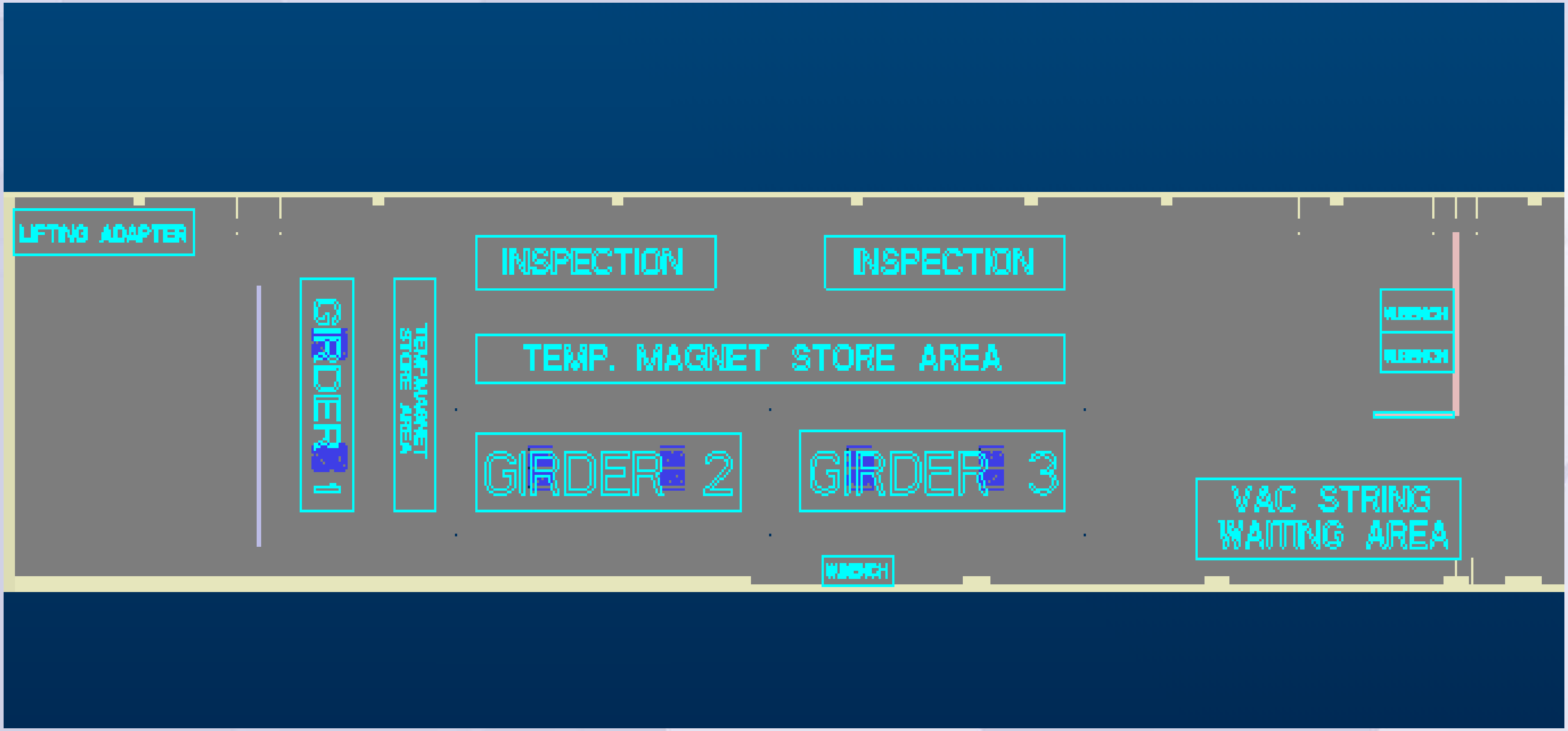
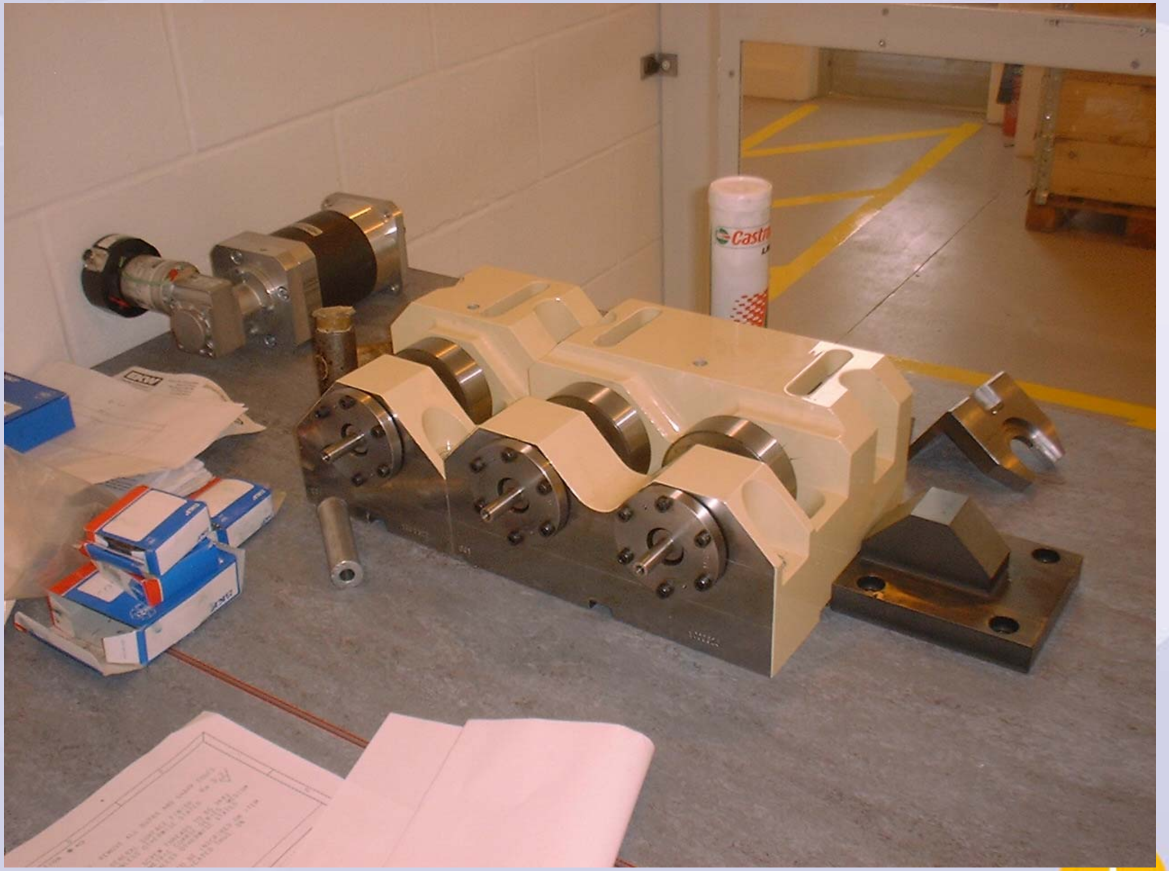
Floor plan of Girder Assembly Area



Vacuum Chamber Bake Oven

Motor driven roller locators



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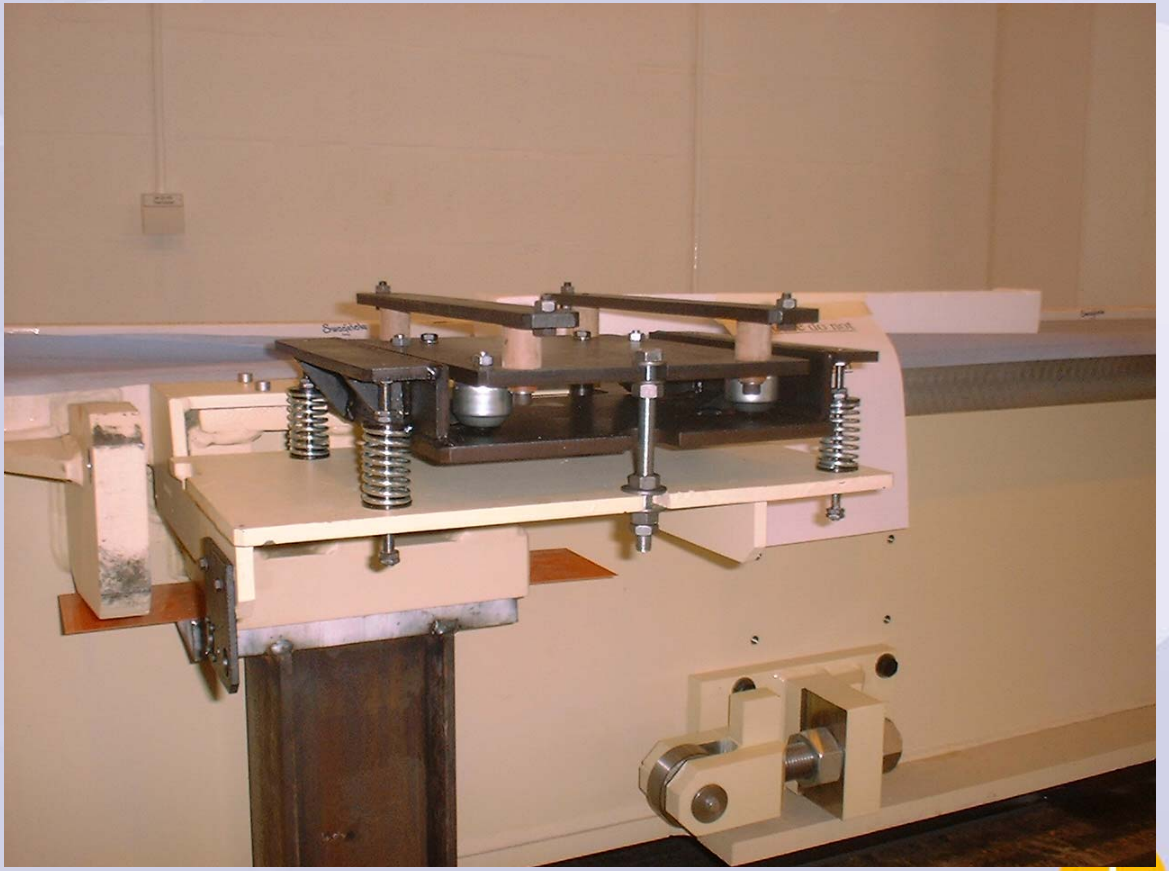
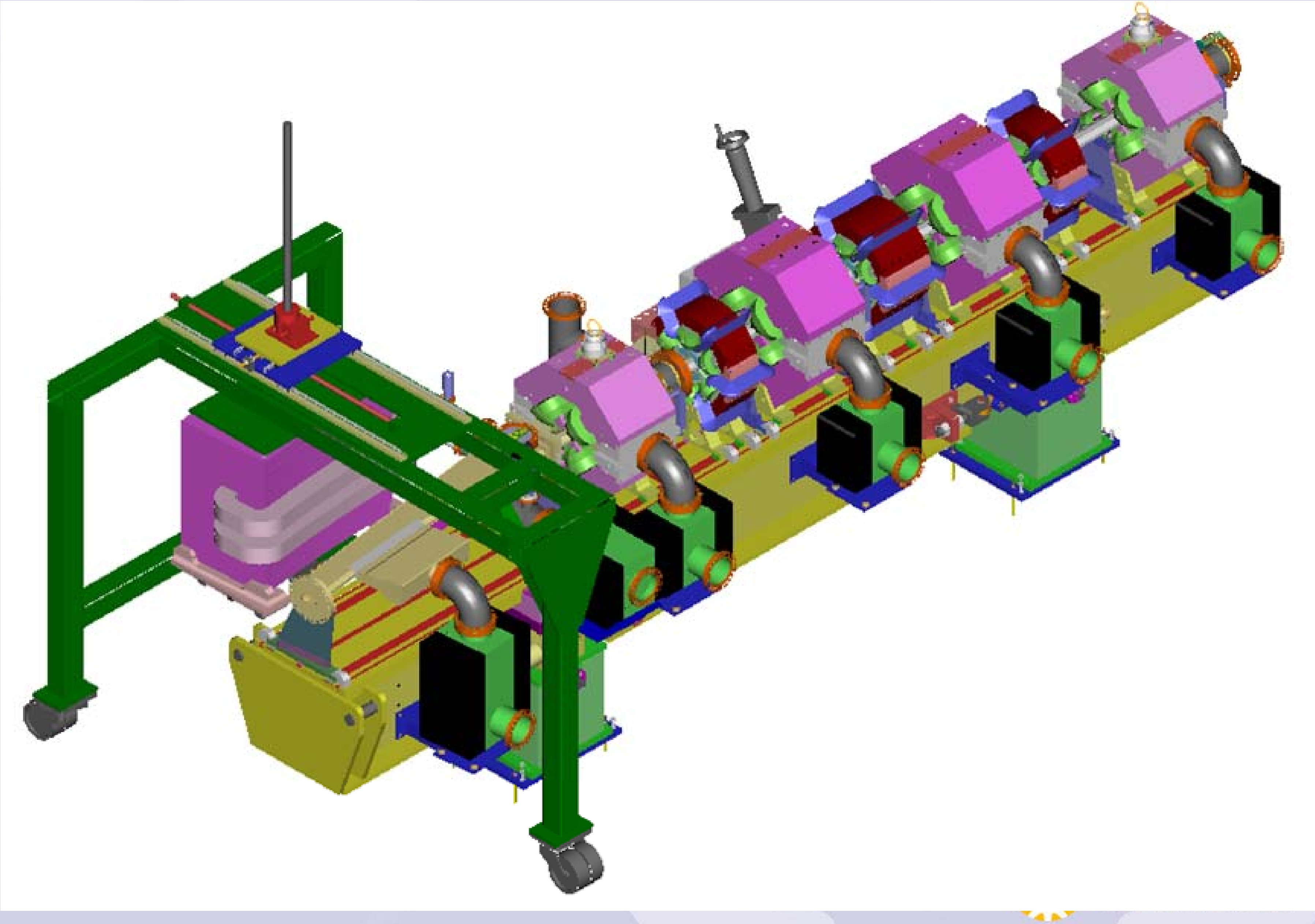
Ion Pump support mounted to Girder



Girder Layout in Assembly Area

Dipole Lifting Arrangement – Installing Dipole onto Girder (# 2 shown)



Survey and Alignment in Assembly Building

R79 SR Girder Floor Plate Alignment using Laser Tracker

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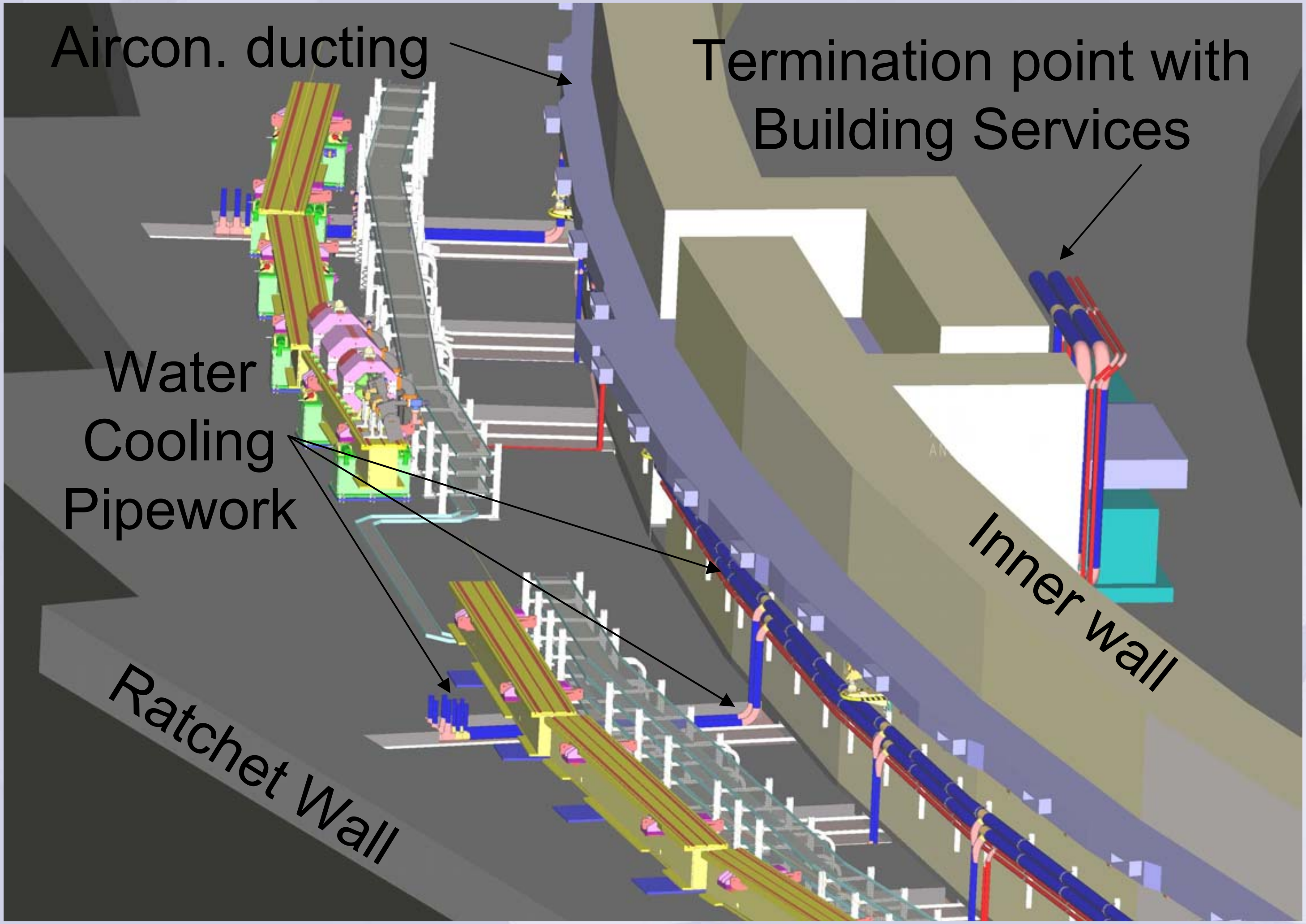
Girder, Magnet and Vessel Delivery Schedule for Girder Assembly

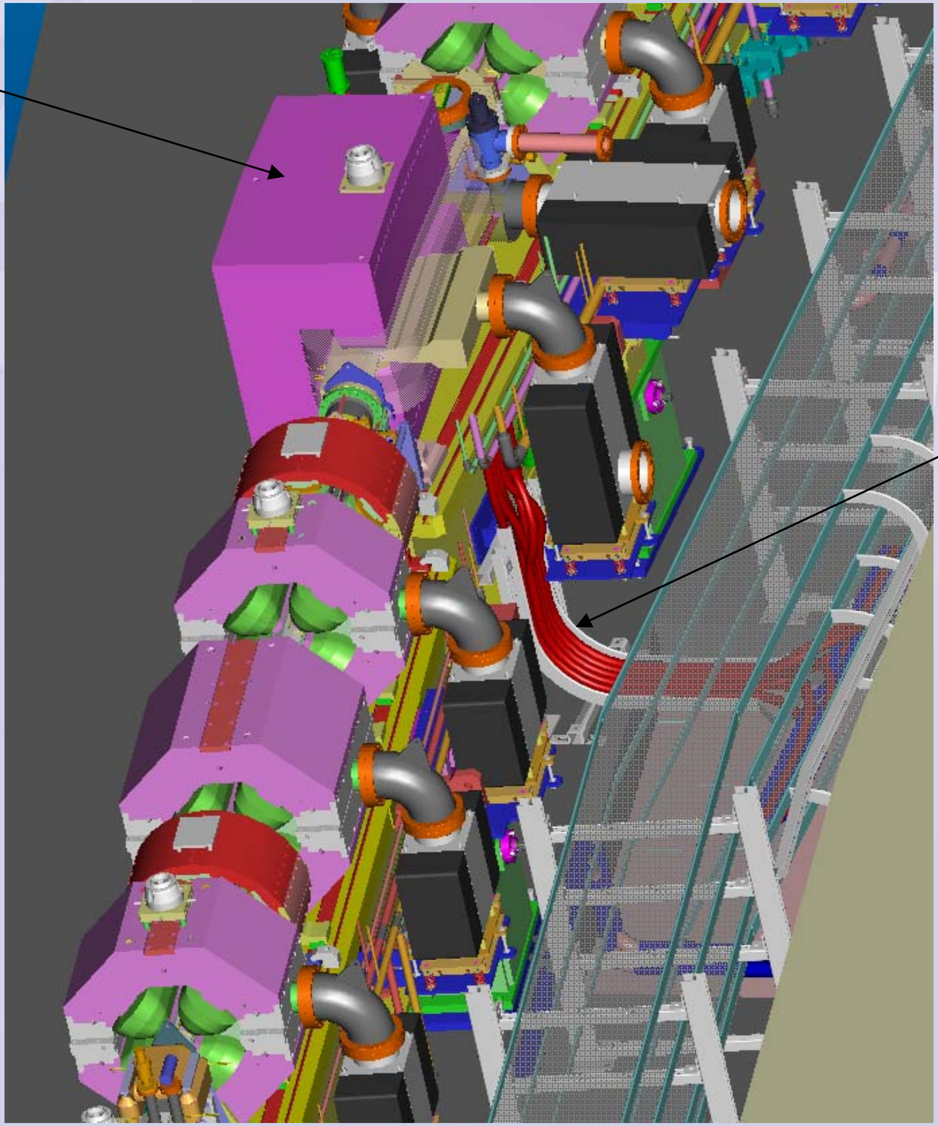
Component	First Delivery	Last Delivery
Vessels Strings	August 2004	August 2005
Girders	July 2004	March 2005
Girder movers	July 2004	April 2005
Quadrupoles	June 2004	June 2005
Dipoles	September 2004	May 2005
Sextupoles	August 2004	May 2005
Vessel Stands	July 2004	March 2005

CAD Model of Storage Ring Services



Example of Dipole Magnet Cabling

Dipole Magnet

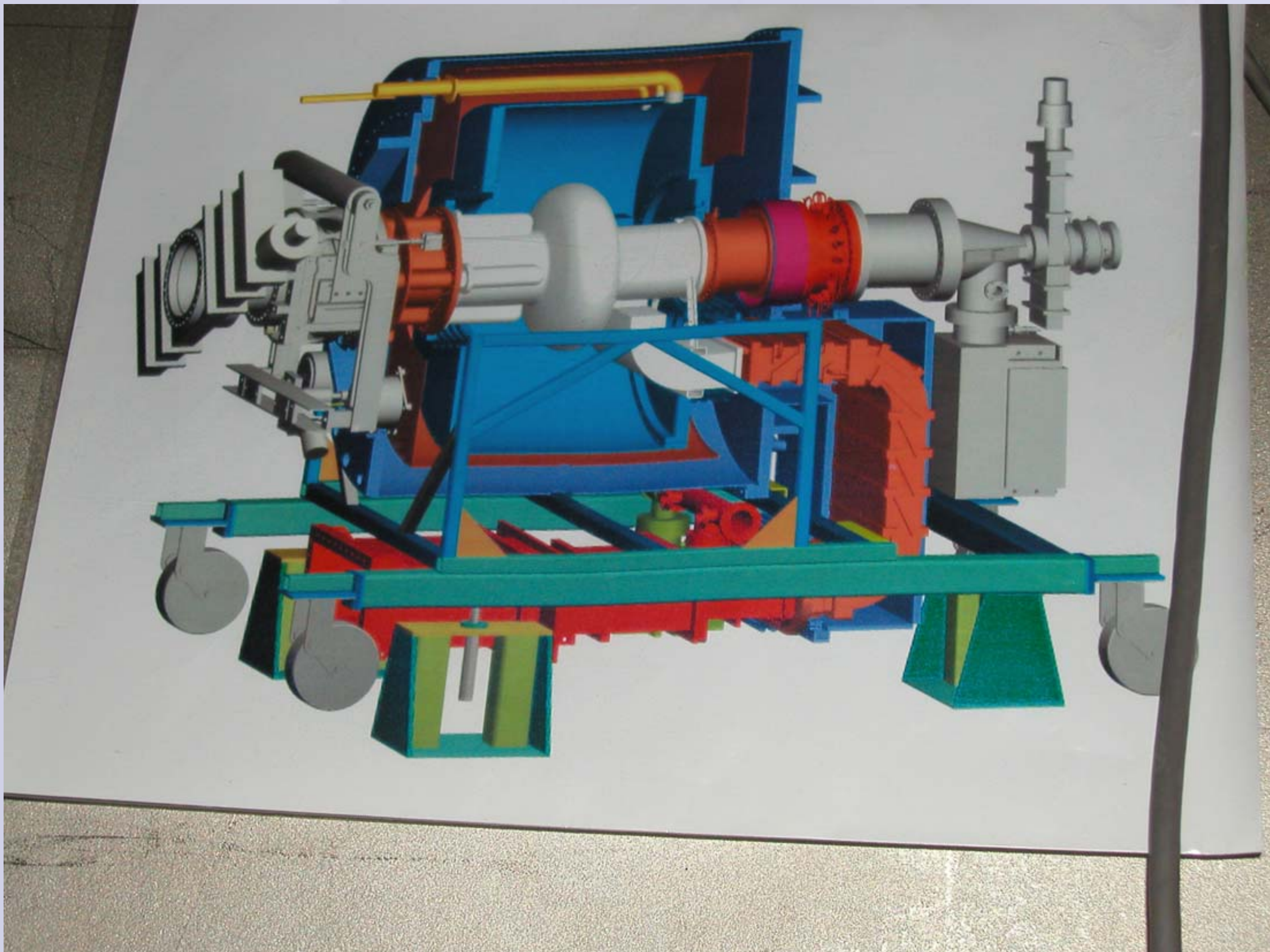


Dipole Cabling

VIII. RF System

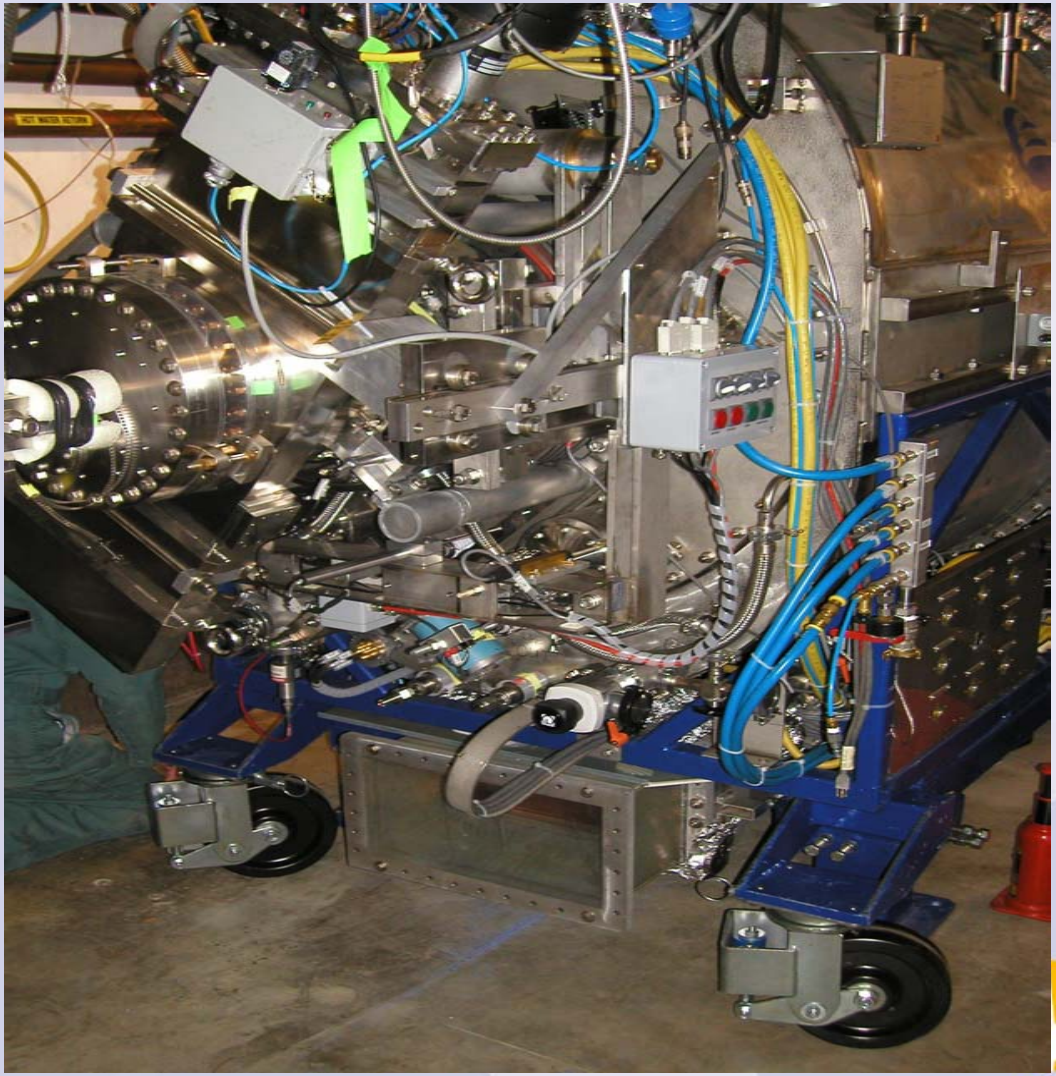
- Three ACCEL/Cornell Modules In Same Straight Section
- Cryogenics Room has its own Slab (Vibration)
- Morten Jensen, RF Group Leader (absent)
- @ Air Liquide (David Grillot, Technical Leader)
- 450 watt @ 4.5K + 150 lit/hr initially, plan to double later (building in mind)
- CLS, Linde type 300-500 Watts
- Problem Encountered, Cryogenics lag building

Animated View of 500 MHz SRF Cryostat



Stripped Module

As Installed



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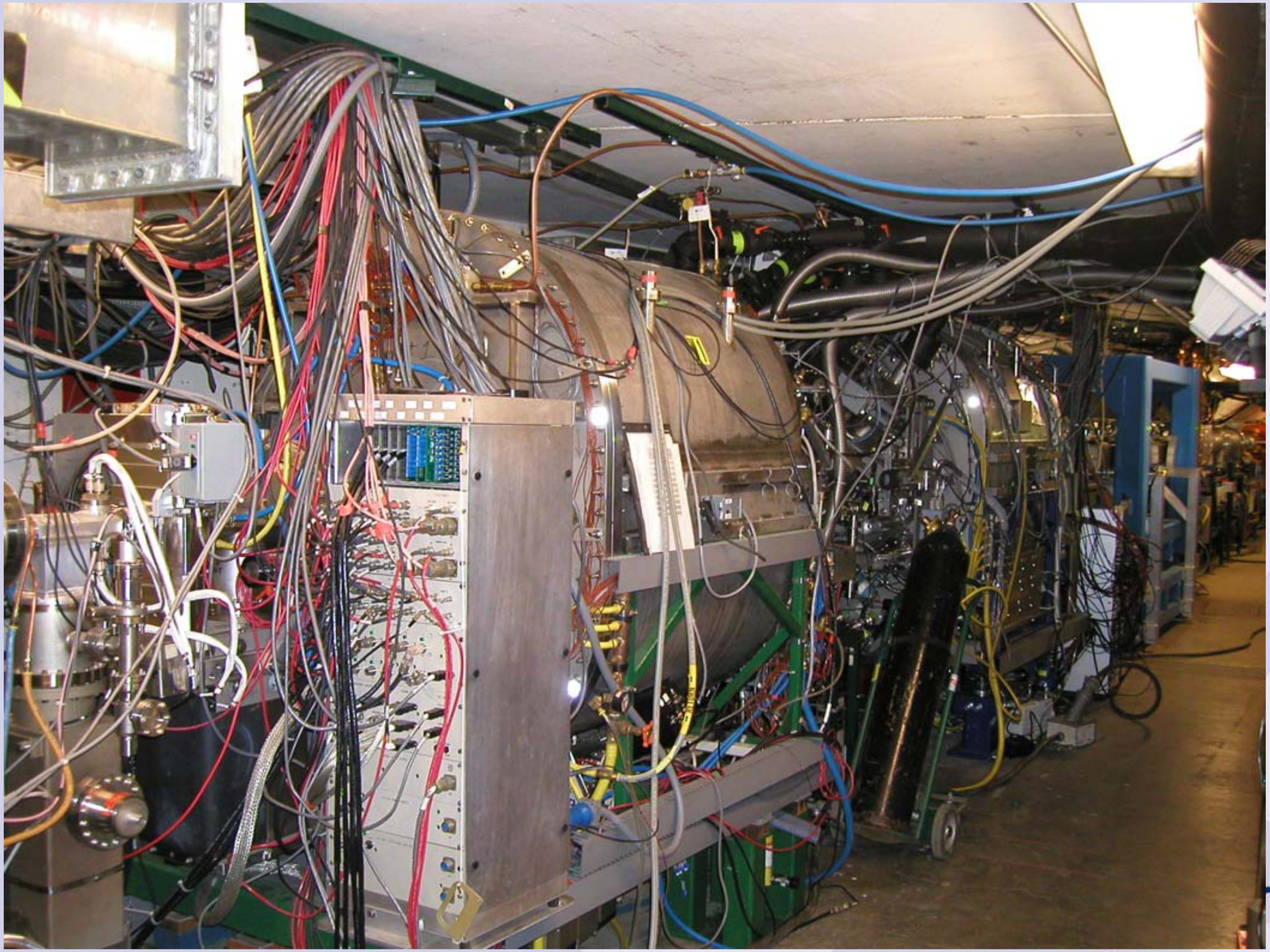
Two Installed Modules



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IX. Booster / Injector

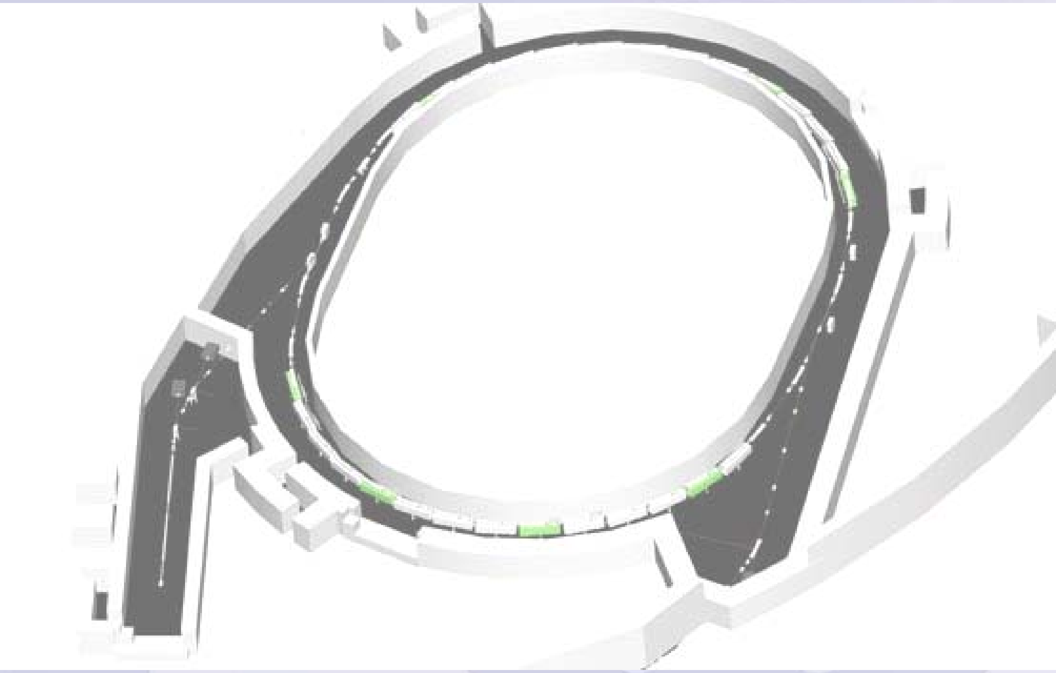
LTB

Booster

BTS

SR Injection

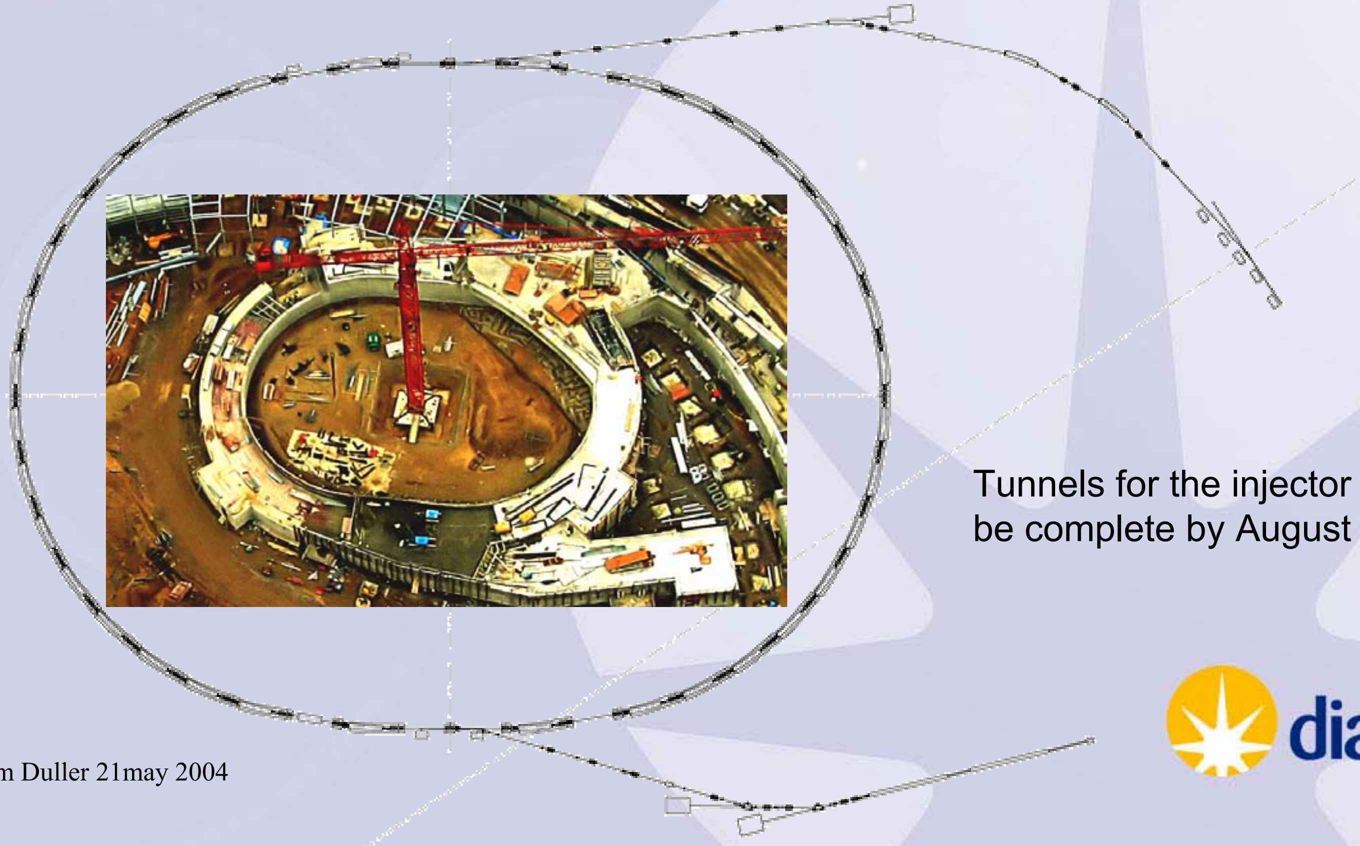
Services



Overview

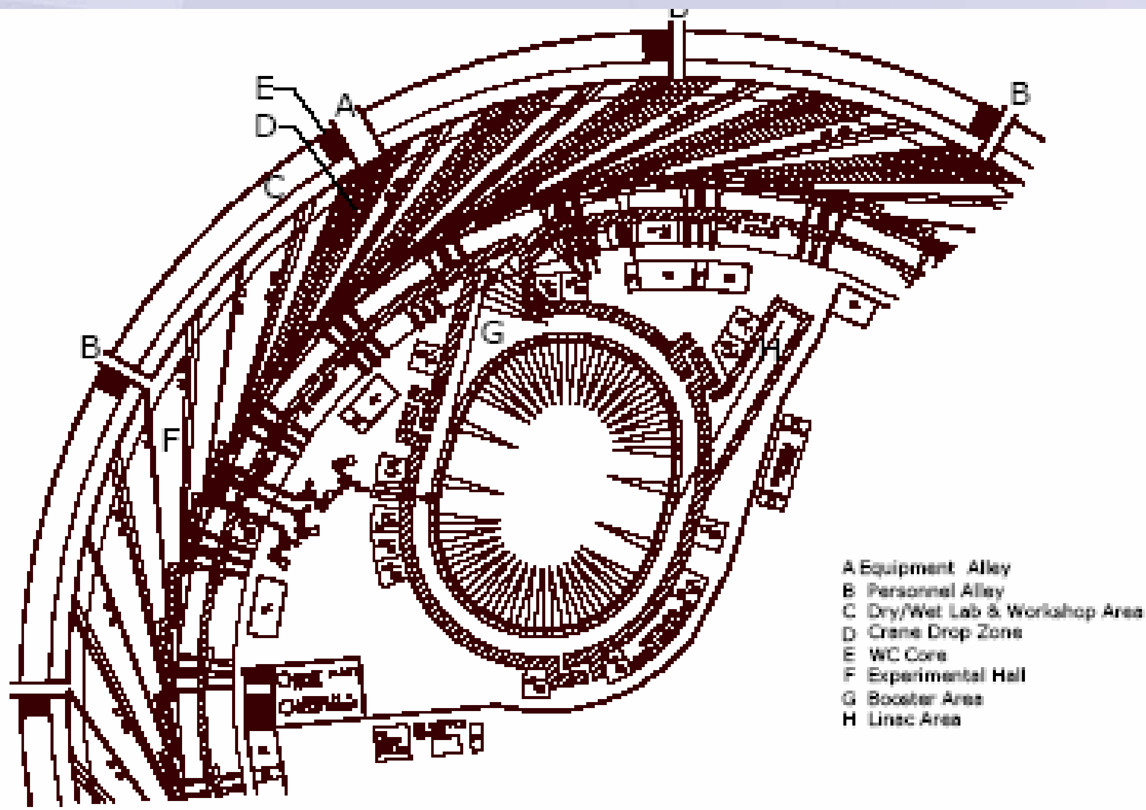
Diamond's injector consists of a 100MeV Linac, a full energy booster, the related transfer lines, injection and extraction elements, and storage ring injection.

The Linac was the subject of Diamonds first major equipment purchase. Accel is building the Linac as a turnkey project to Diamond's performance specification. The design is closely based on the Linac installed at the SLS.



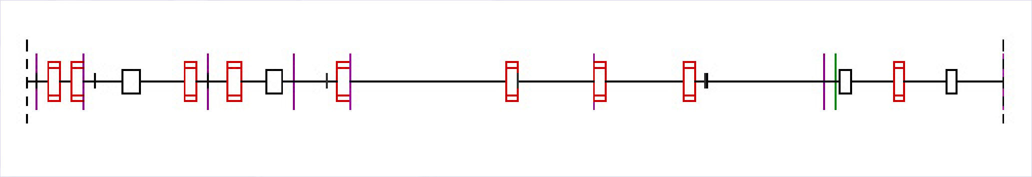
Tunnels for the injector will be complete by August 2004.

Linac-Booster



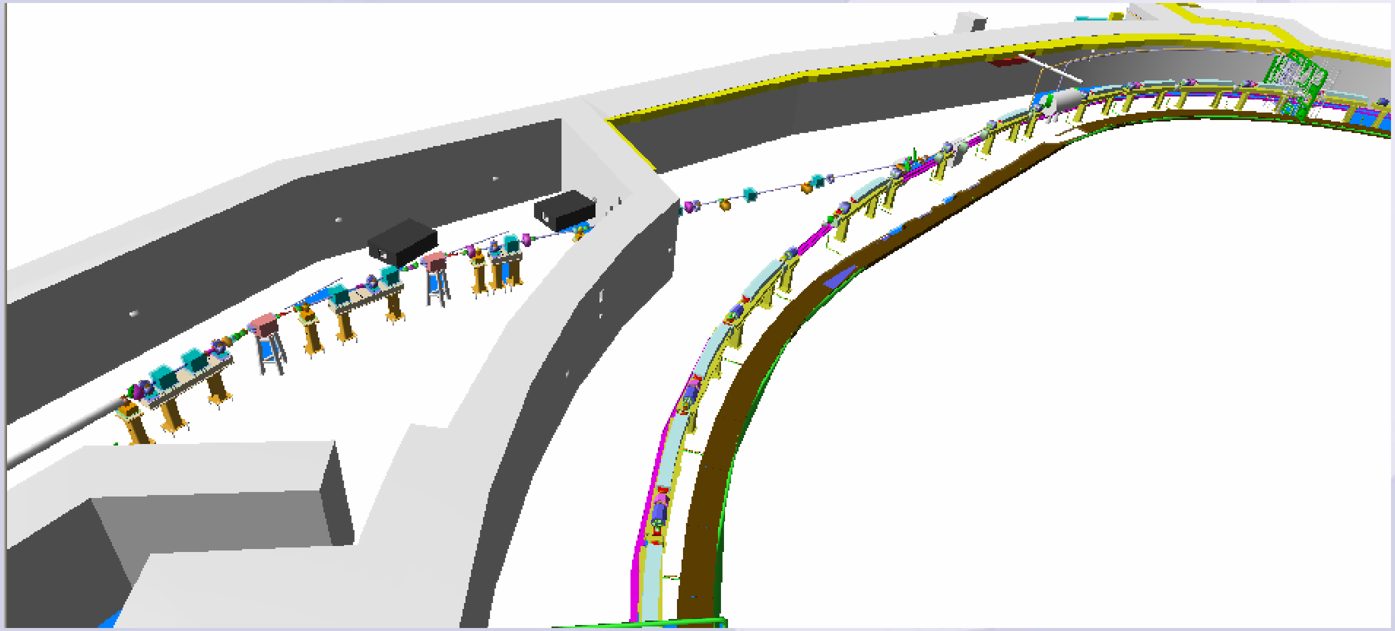
: Layout showing linac and booster

LTB (Linac to Booster transfer line)



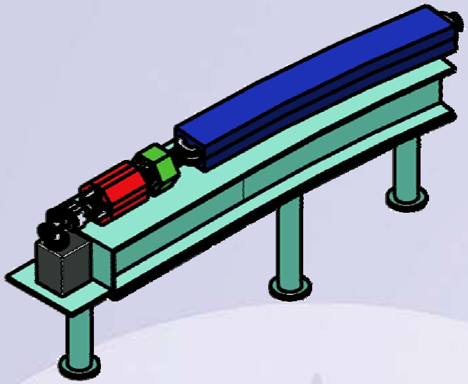
Magnets for the transfer lines will be integrated with vessels, stands and other components designed by Diamond.

- 2 Dipoles, 7 Quads and correctors
- Magnets on order from Danfysik
-Procured to performance spec.
- Quad inscribed radius 28mm, length 250mm Max Gradient 4 T/M
- Dipole Vert aperture 42mm, yoke arc length 650mm, pk field 0 .175T.

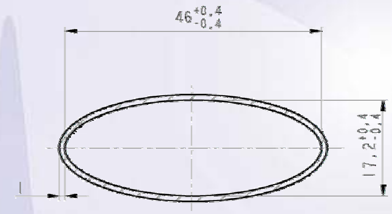


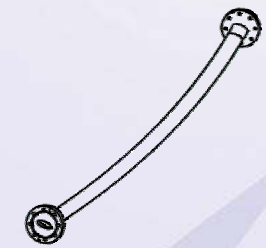
Booster

The booster will accelerate electrons from 100MeV to 3GeV. The majority of the booster, consisting of 36 dipoles, 44 quadrupoles, 28 sextupoles, and 44 correctors, will be mounted on pre-assembled girders. Danfysik will complete the detail design, production, and assembly of these elements. Diamond will be responsible for installation and commissioning.



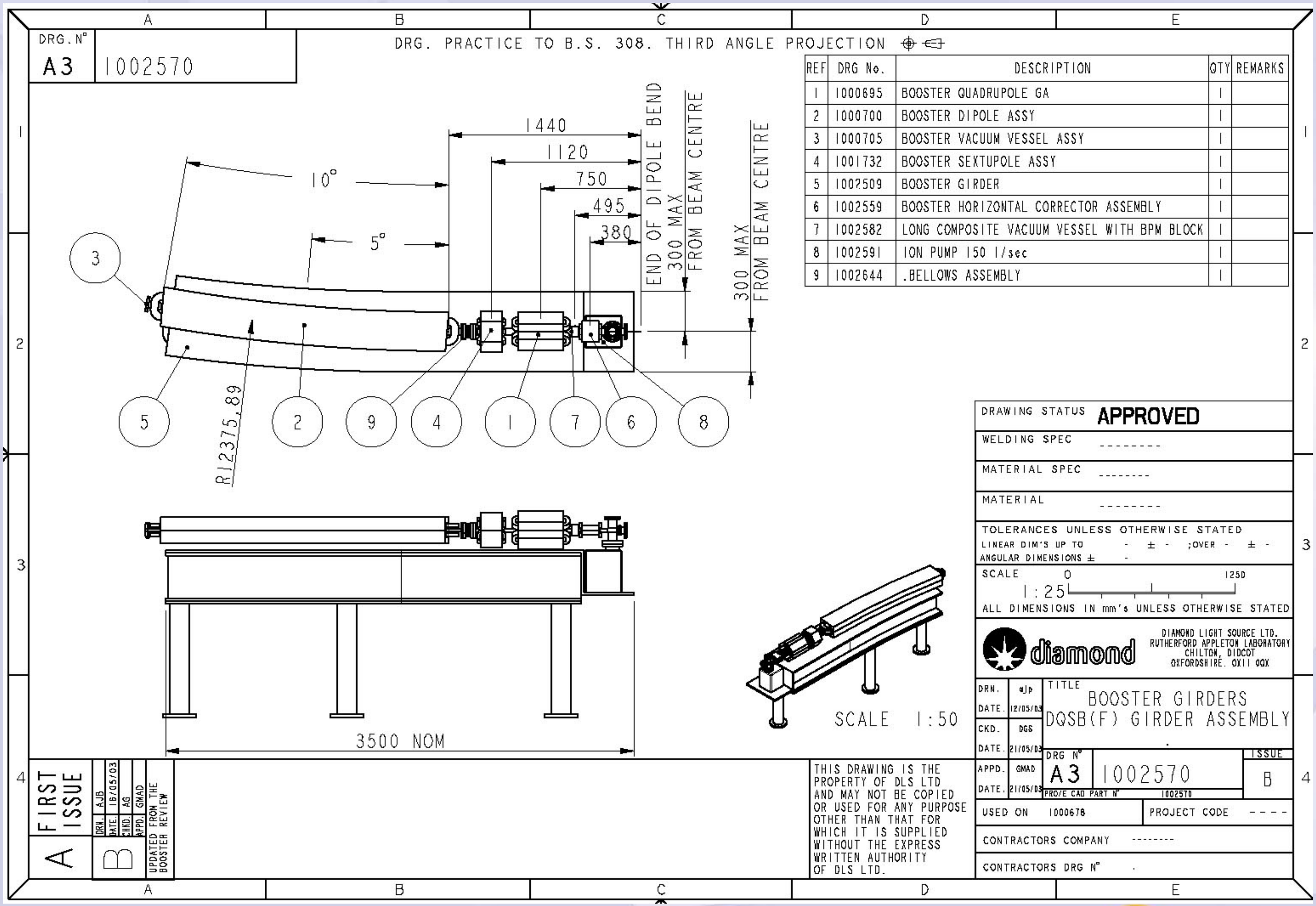
A compact booster vessel design allows reduced magnet apertures, lighter structures, and improved efficiency.





Booster circumference:	158.4m
Repetition rate:	5Hz
Injection energy:	100MeV
Extraction energy:	3GeV
RF frequency:	499.654MHz
Nominal current:	3.17mA

Typical girder assembly drawing



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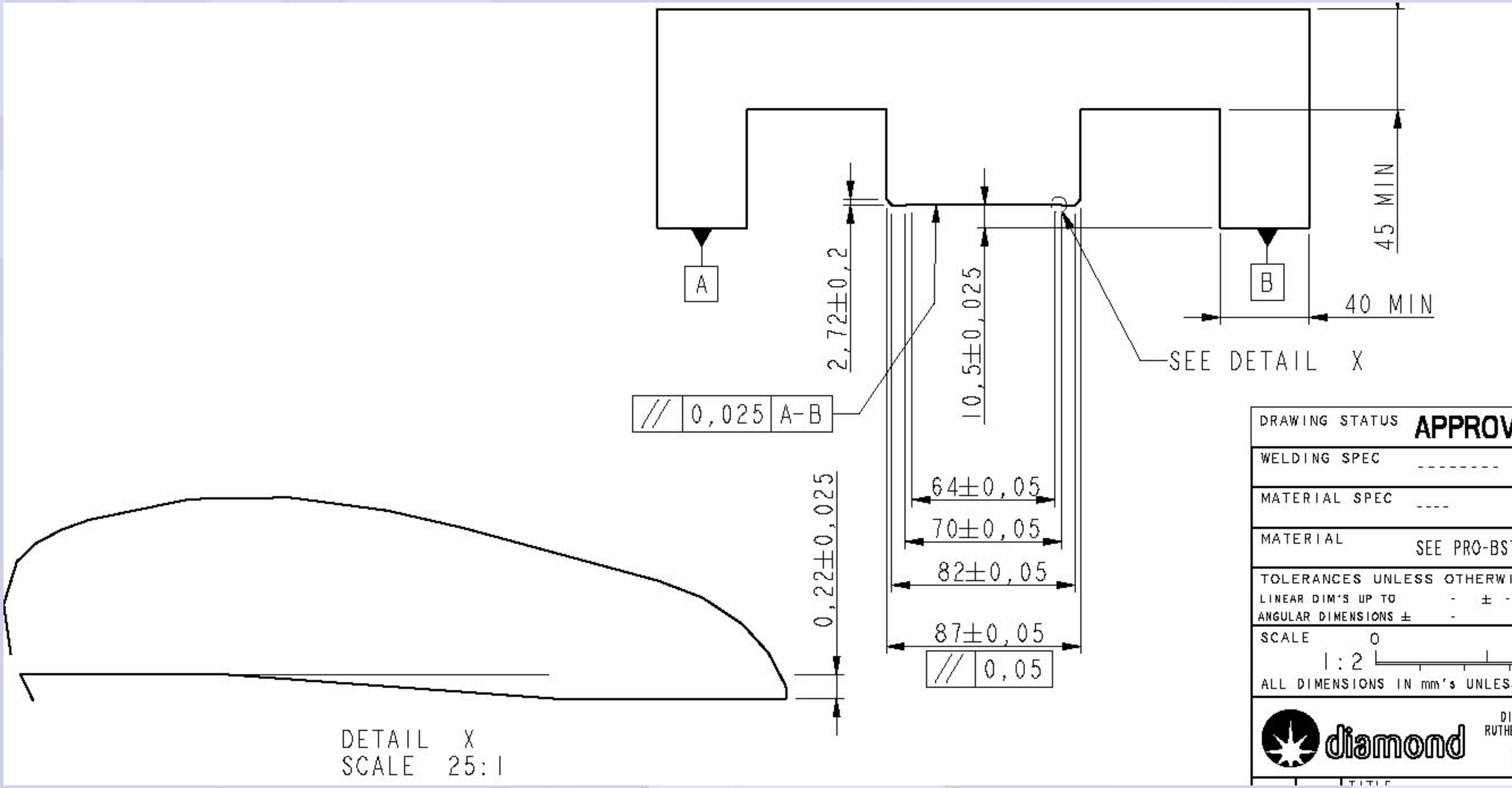
Magnet Lamination Drawing



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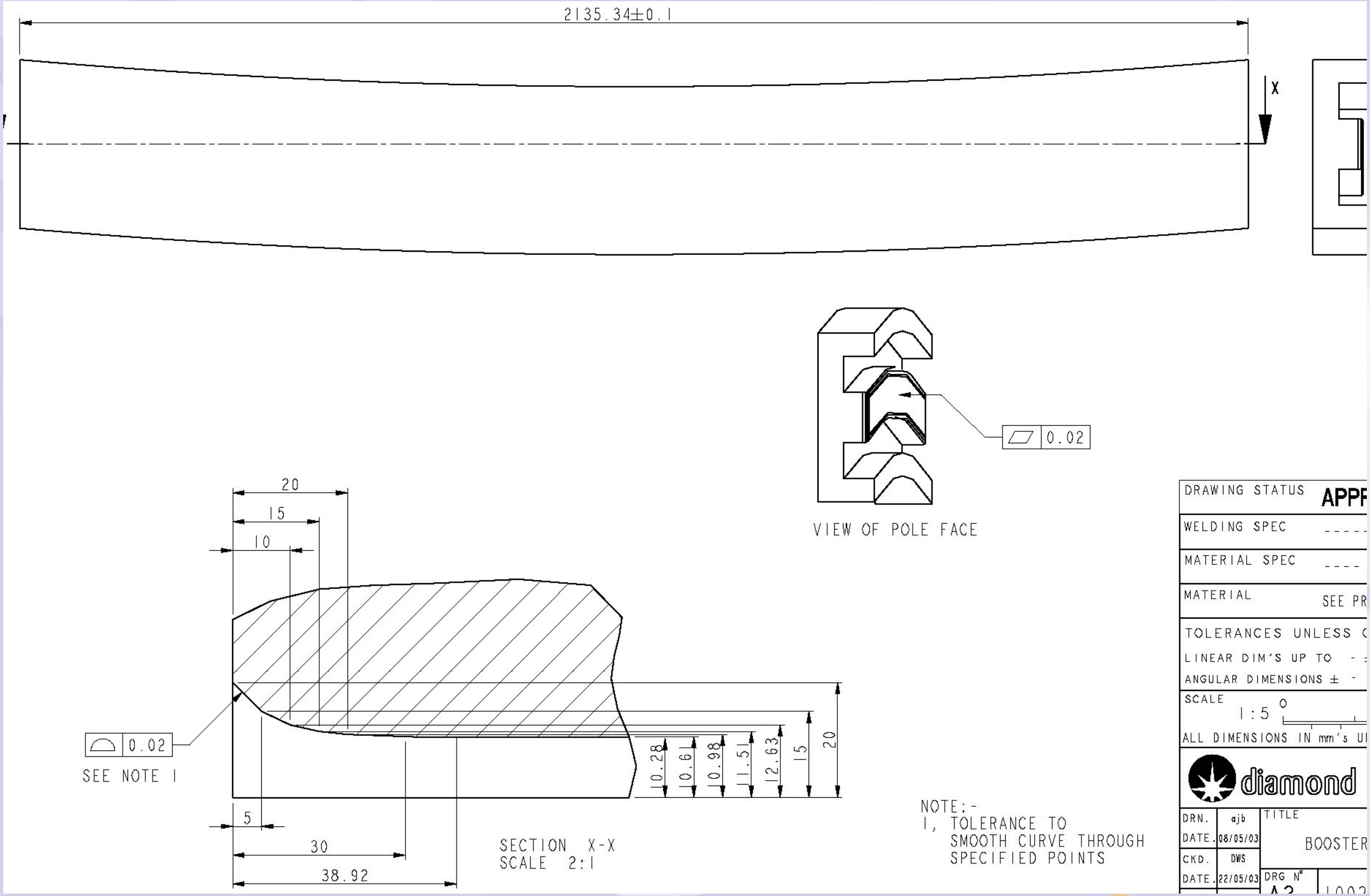
Magnet Block Drawing



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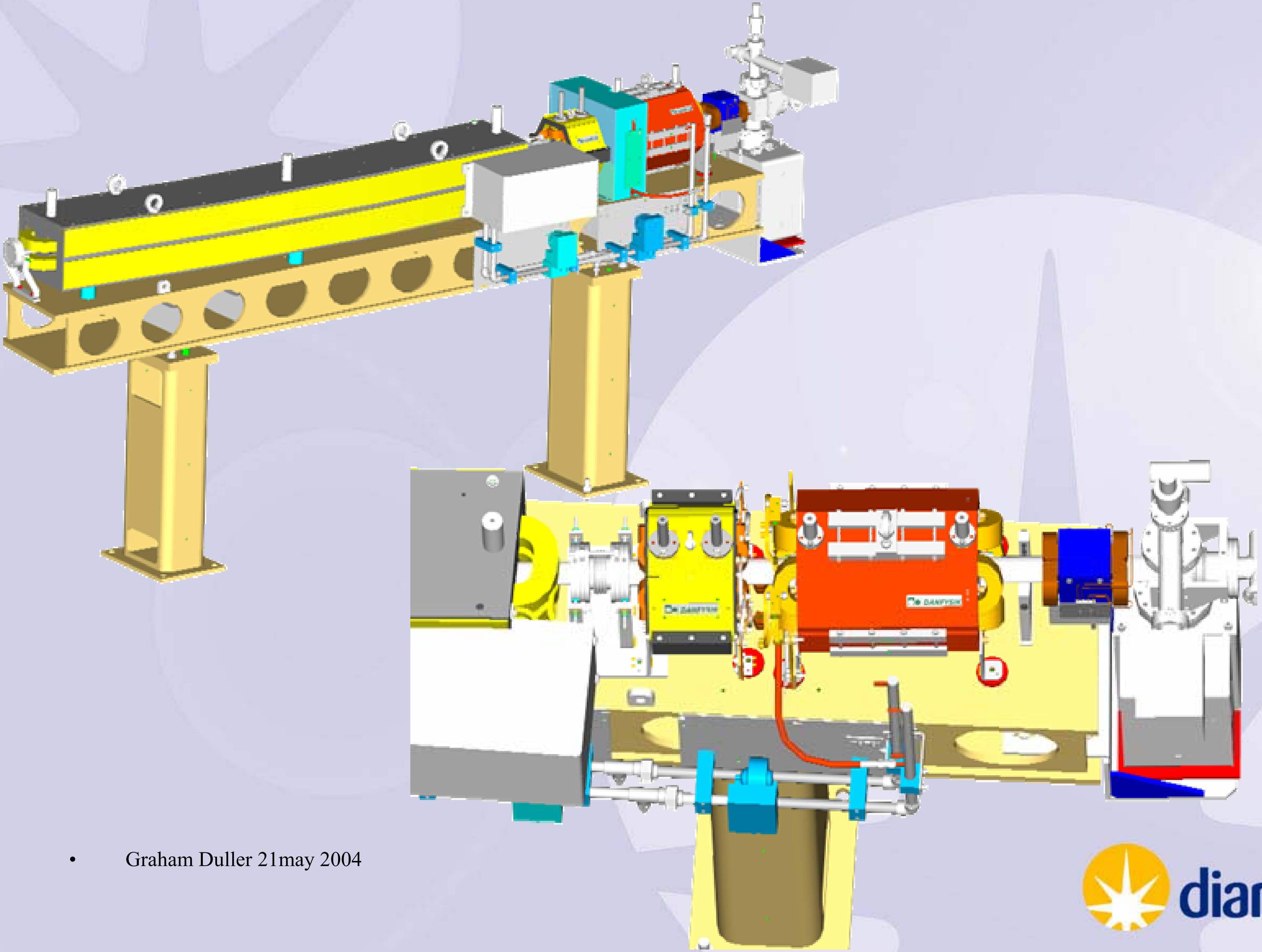
Booster Girder Models



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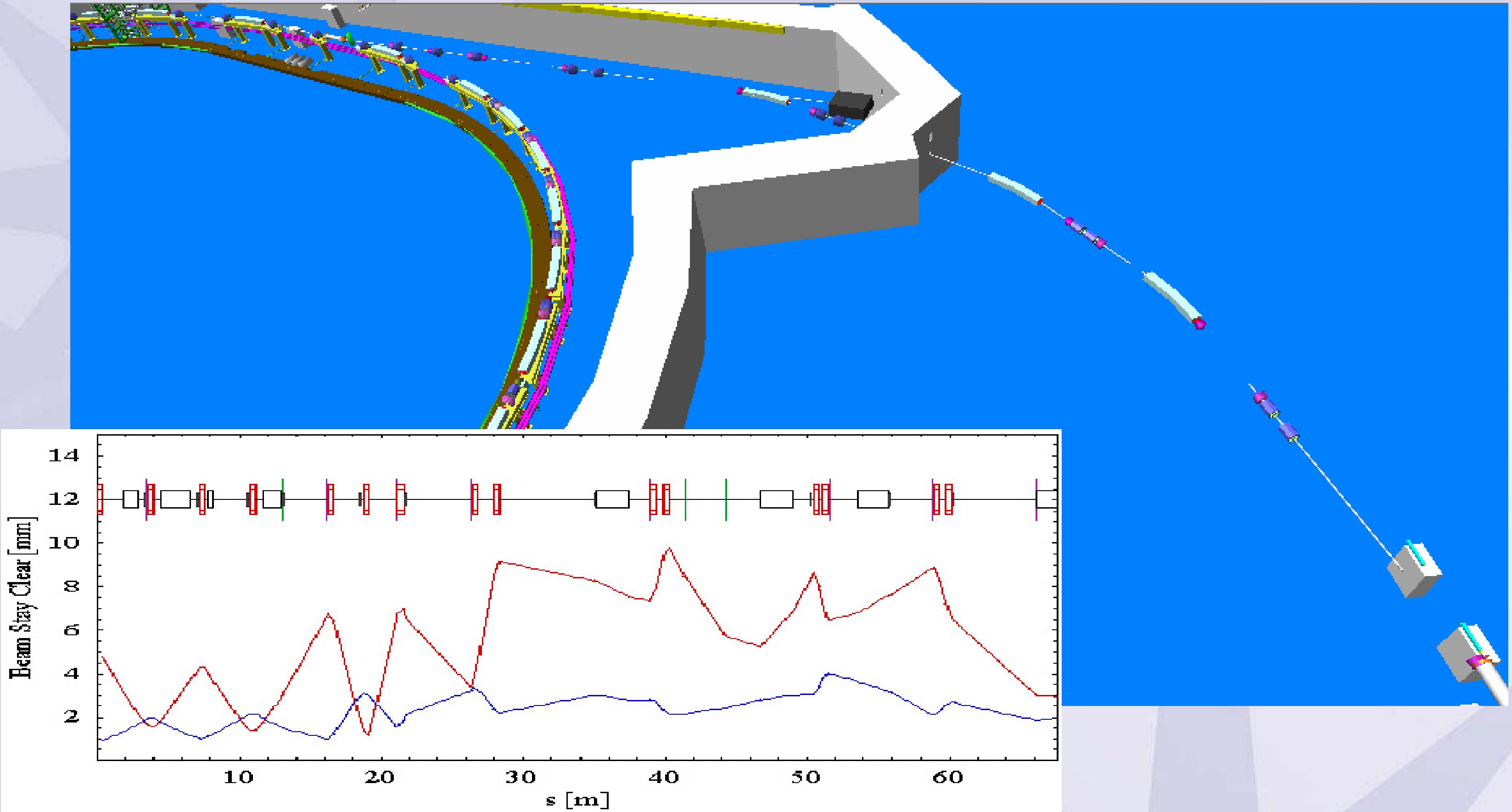
BTS (Booster to Storage ring transfer line)

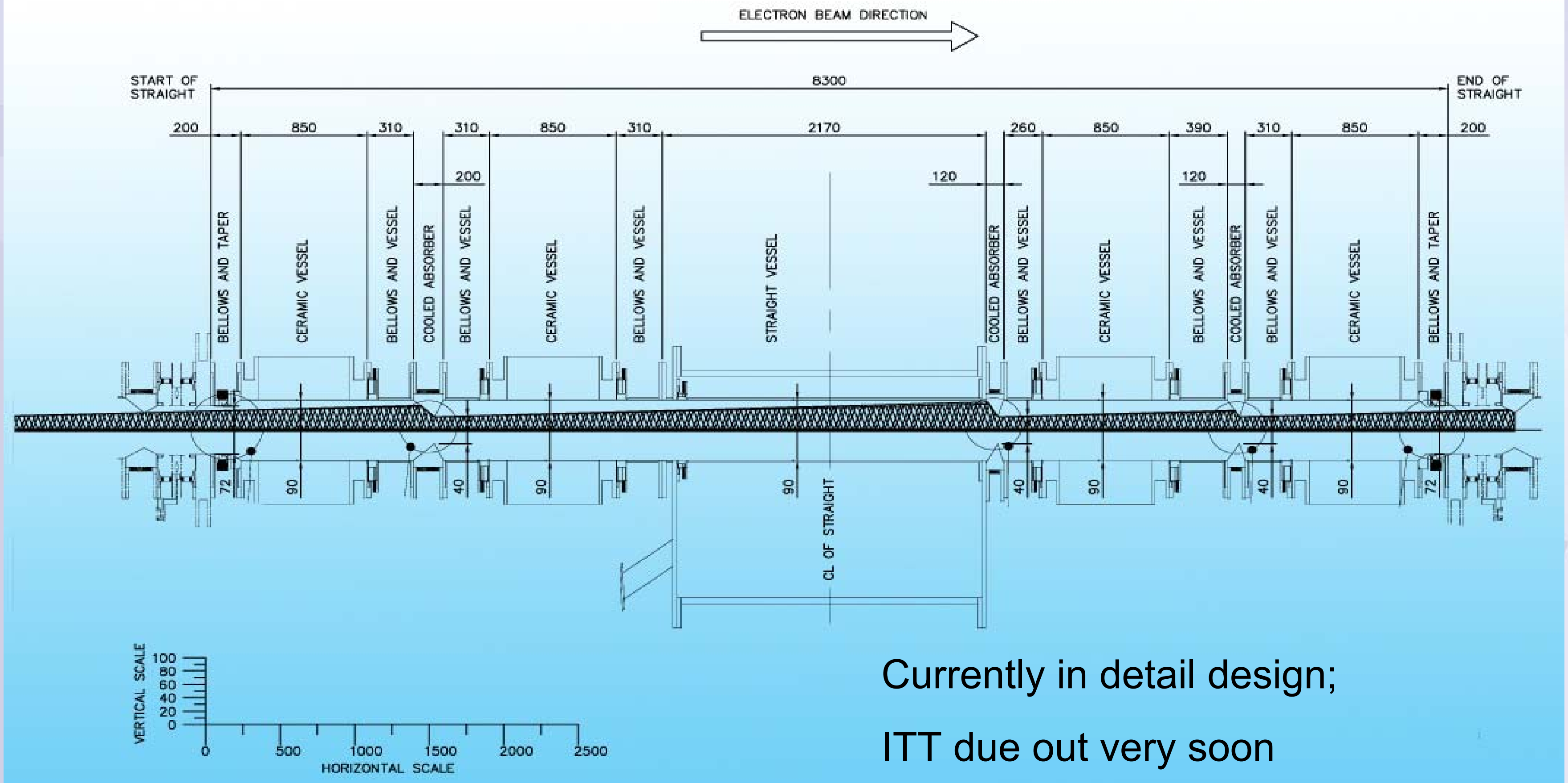


Procurement similar to the LTB line

Magnet ITT due in June 2nd

Evidence of supplier overload becoming apparent

Storage ring injection straight



Currently in detail design;

ITT due out very soon

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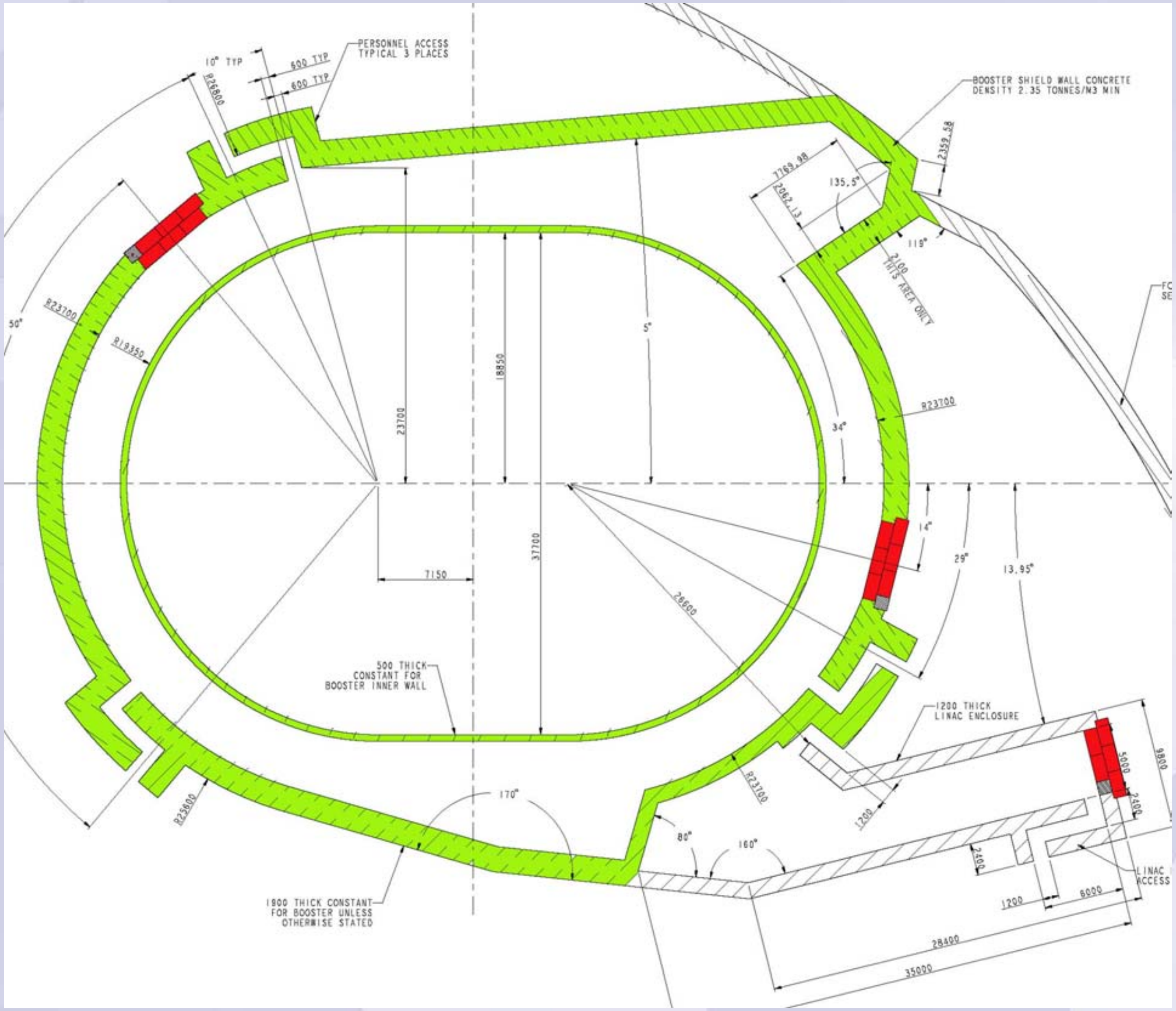
Services

- Air Con
- Water
- Comp Air
- All run through personnel labyrinths
- Services must match the equipment; can be difficult with pre-existing designs!



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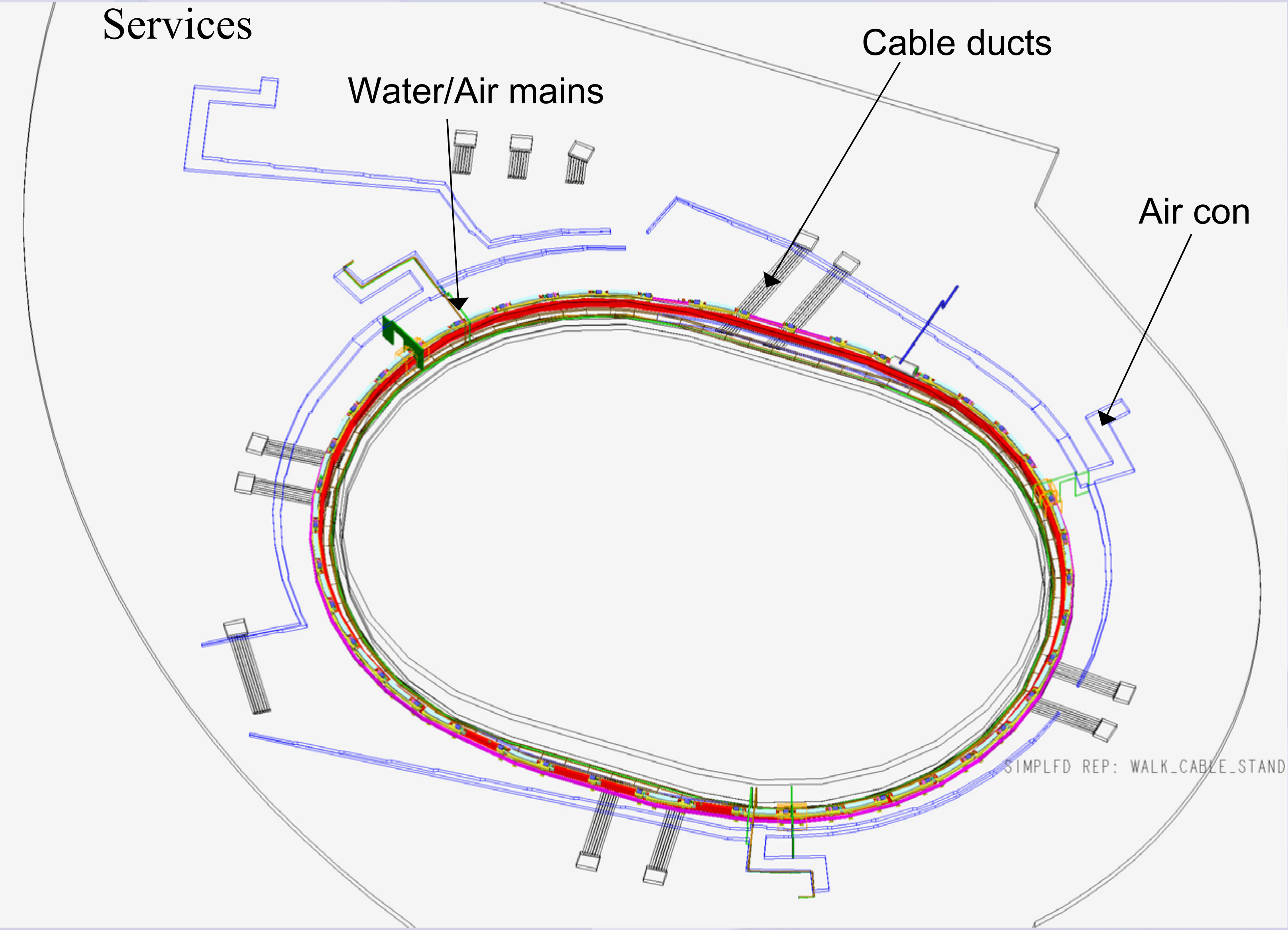
Services



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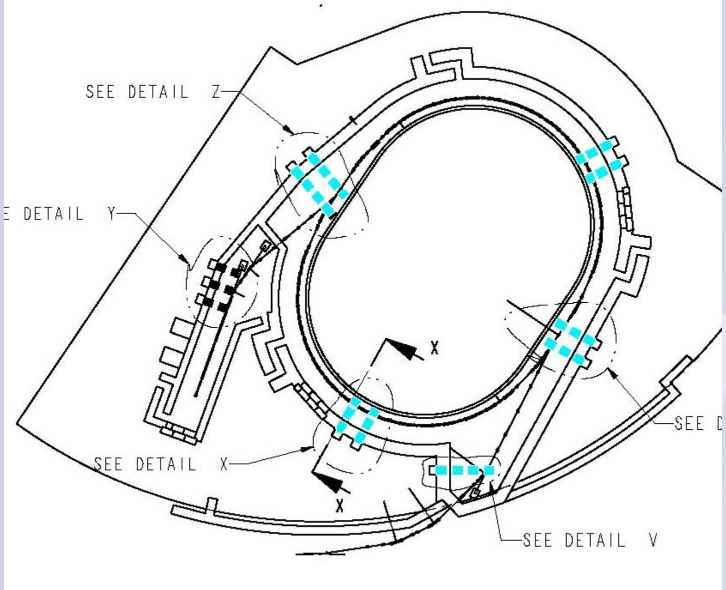
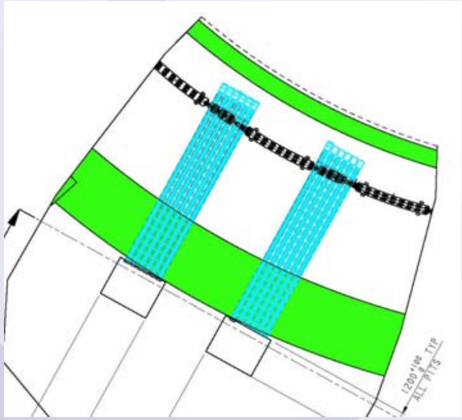
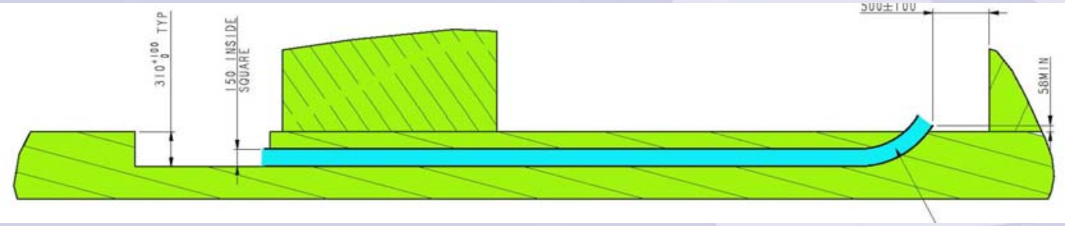
Services

- Cable runs;
- Dipoles through personnel labyrinths
- Other cables ducted
- Steel tubes embedded below concrete floor







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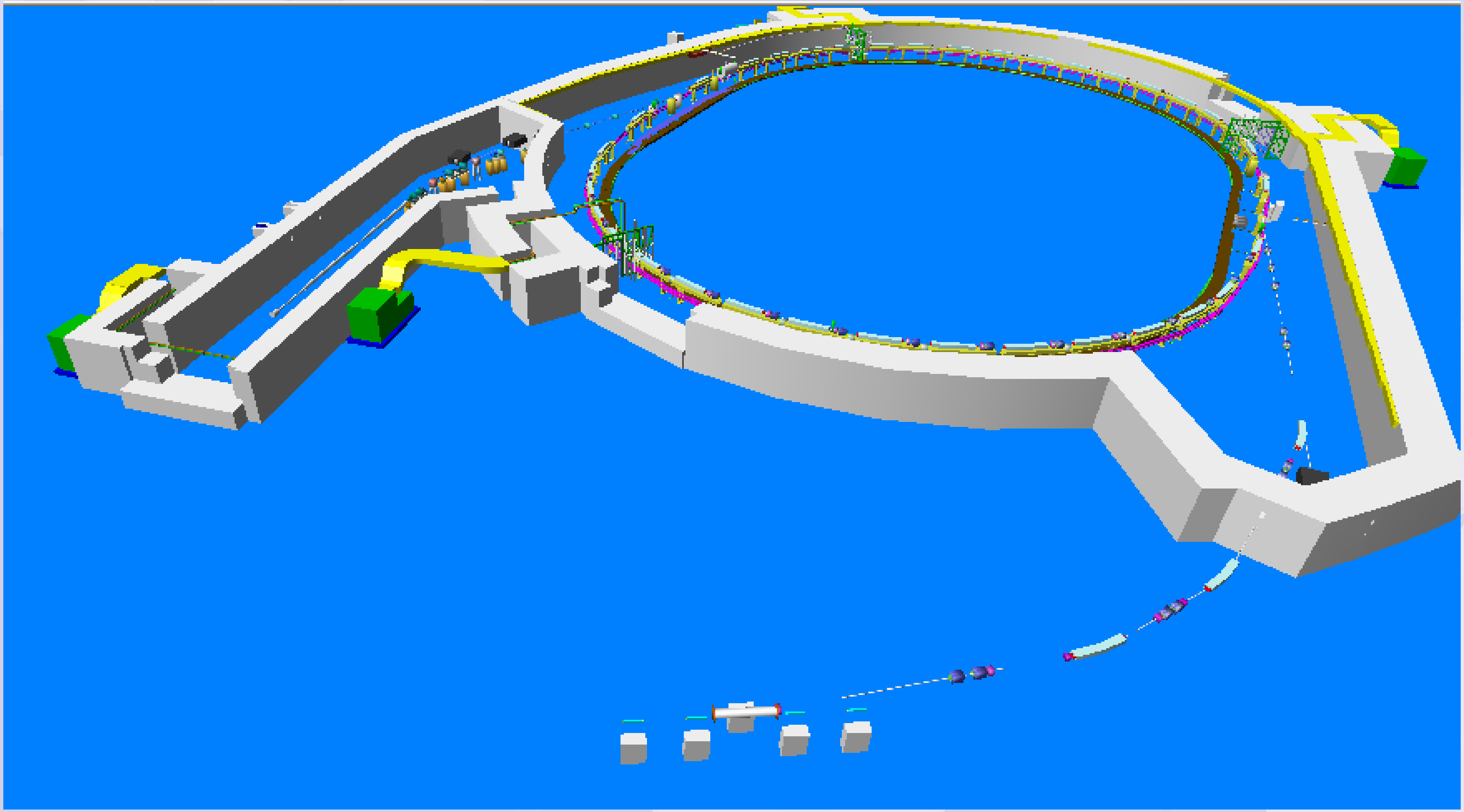
…and when it's all put together…



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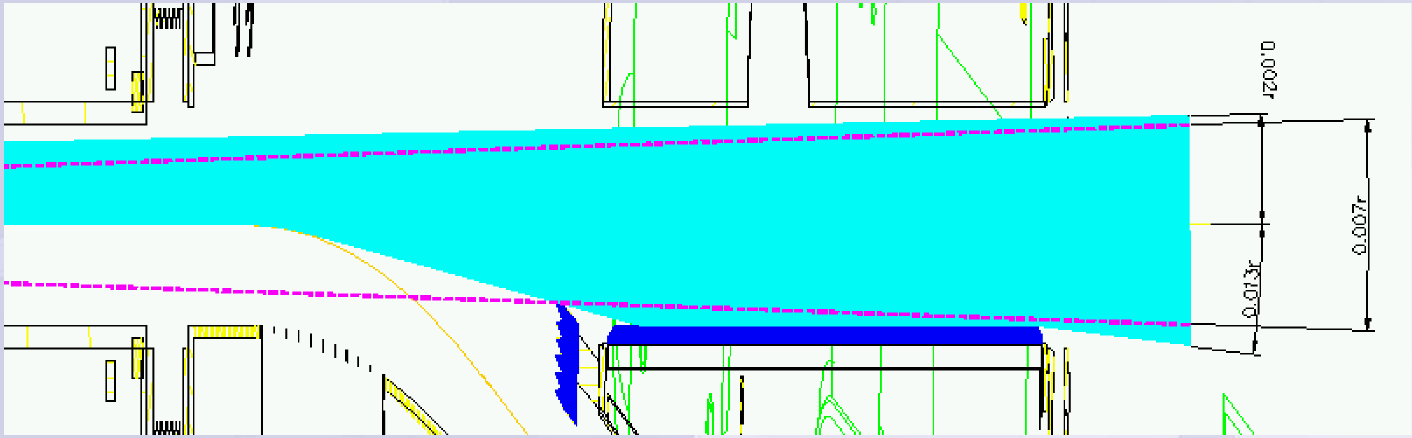
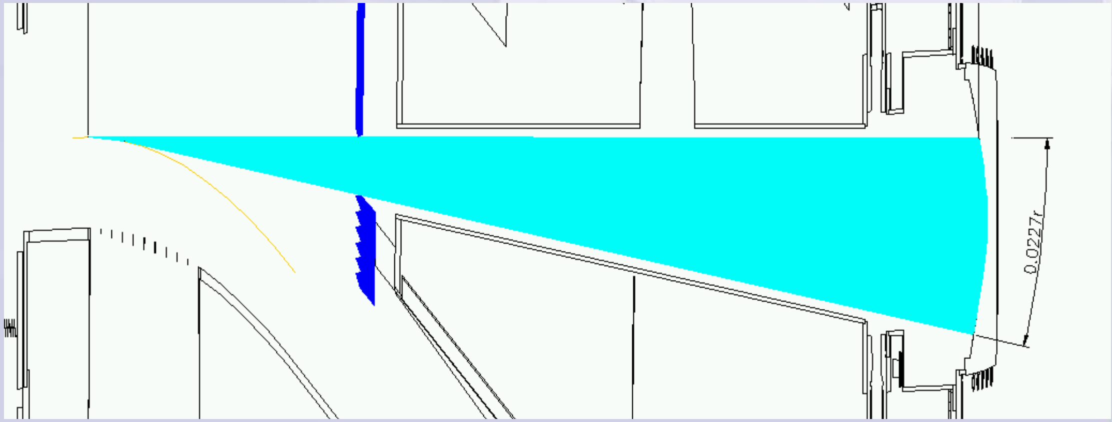
X. Front Ends

Front-end Entrance Fan

Each ID port in the storage ring allows 7x 1mRad ID radiation into the FE



Each BM port in the storage ring allows 22.7 x 3mRad BM radiation into the FE



Year 1 Beamlines

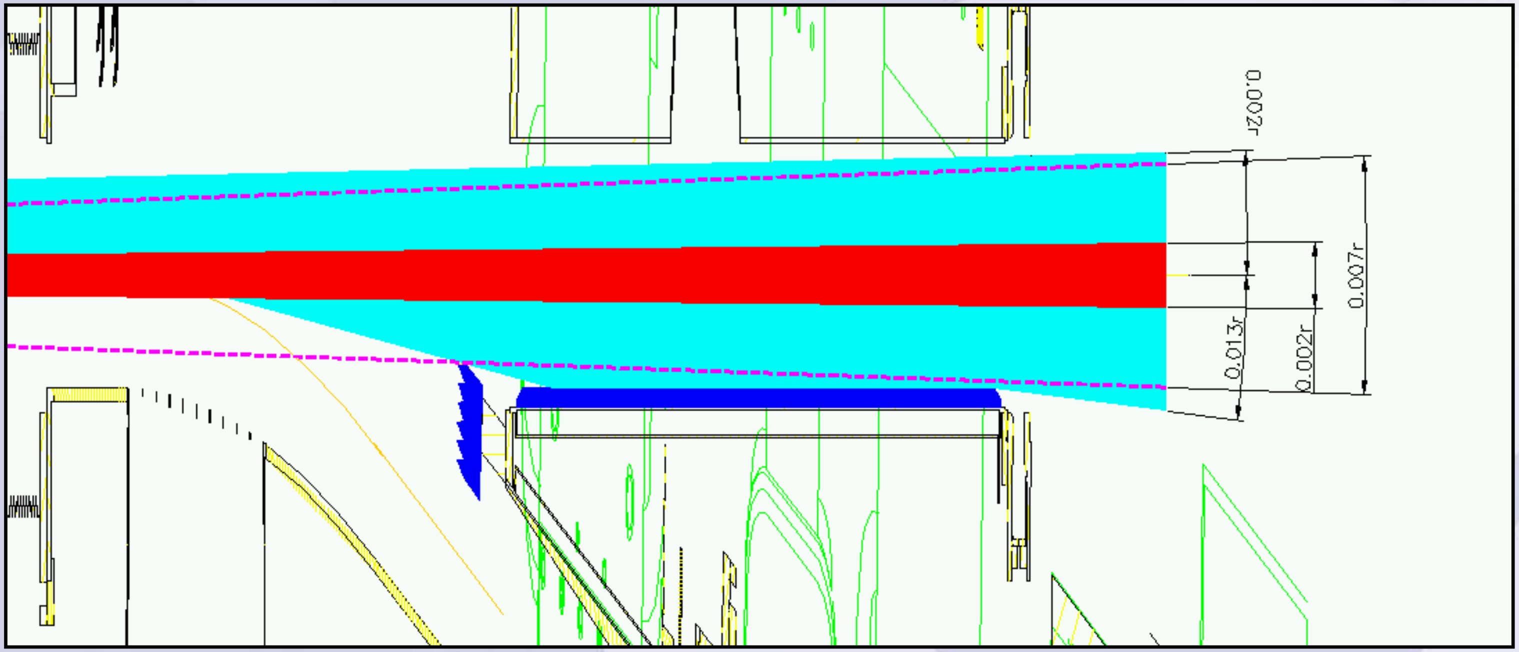
Beamline	Location	Type	Monitoring Aperture		Final Aperture	
			H(mRad)	V(mRad)	H(mRad)	V(mRad)
Extreme Conditions	**ID 15**	SCW	N/A	0.5	+/-0.25 +1.35 +1.65 -1.35 -1.65	0.500 0.300 0.300
Materials and Magnetism	**ID 16**	Undulator	1	0.5	0.150	0.075
Protein Crystallography	**ID 2,3,4**	Canted Undulators	2	0.5	0.130	0.050
XAS Microfocus	**ID 18**	Undulator	1	0.5	0.150	0.075
Nanostructures	**ID 6**	2 Co-Axial Apple devices	1.6	1	0.300	0.250

Standard Undulator front-end with maximum aperture of 2.0mRadH x 1.0mRadV through PBPMs, customised after 2nd PBPM.

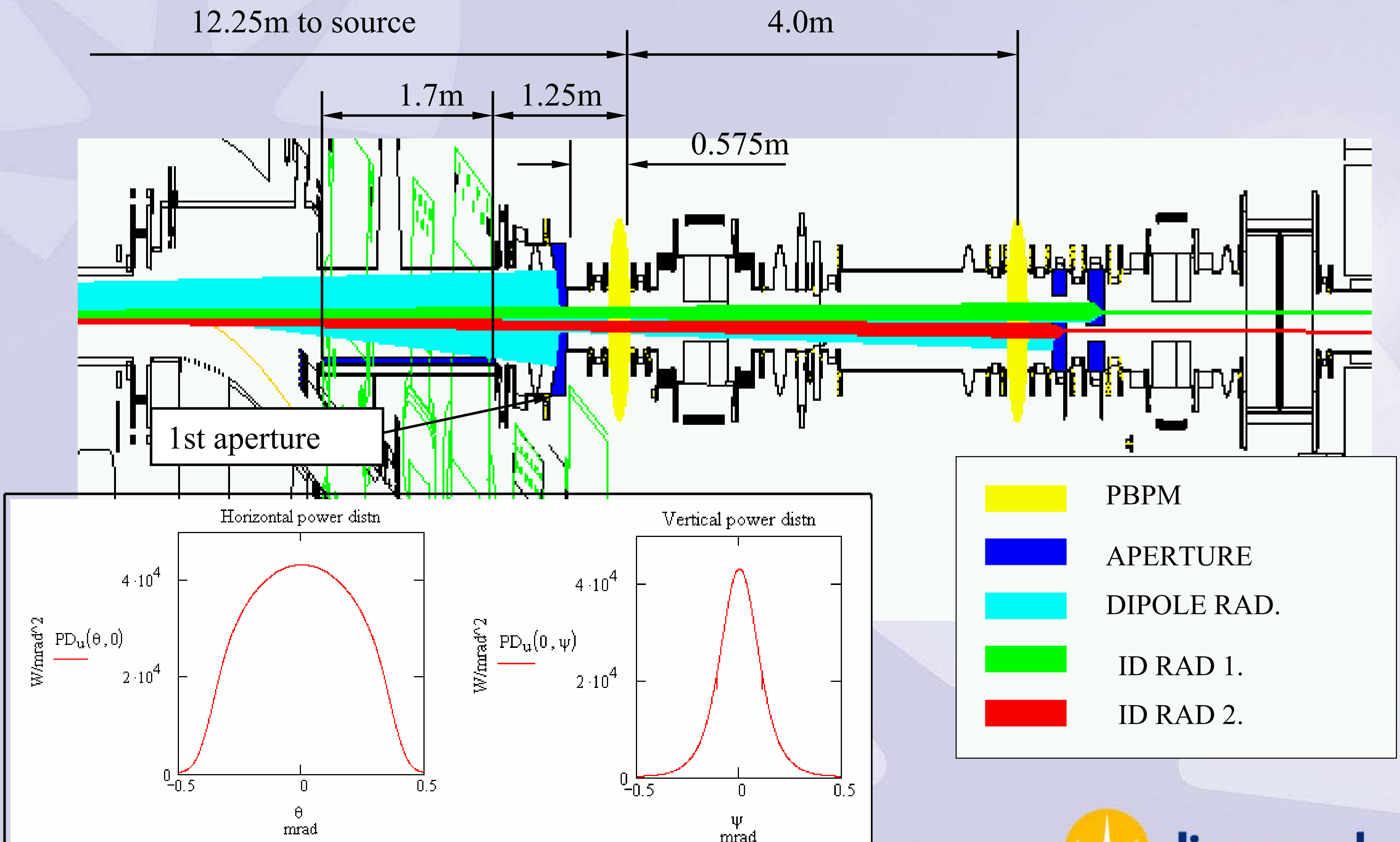
Front-end Entrance Fan

Storage ring lets 7mrad x 1mrad ID radiation into each ID front-end

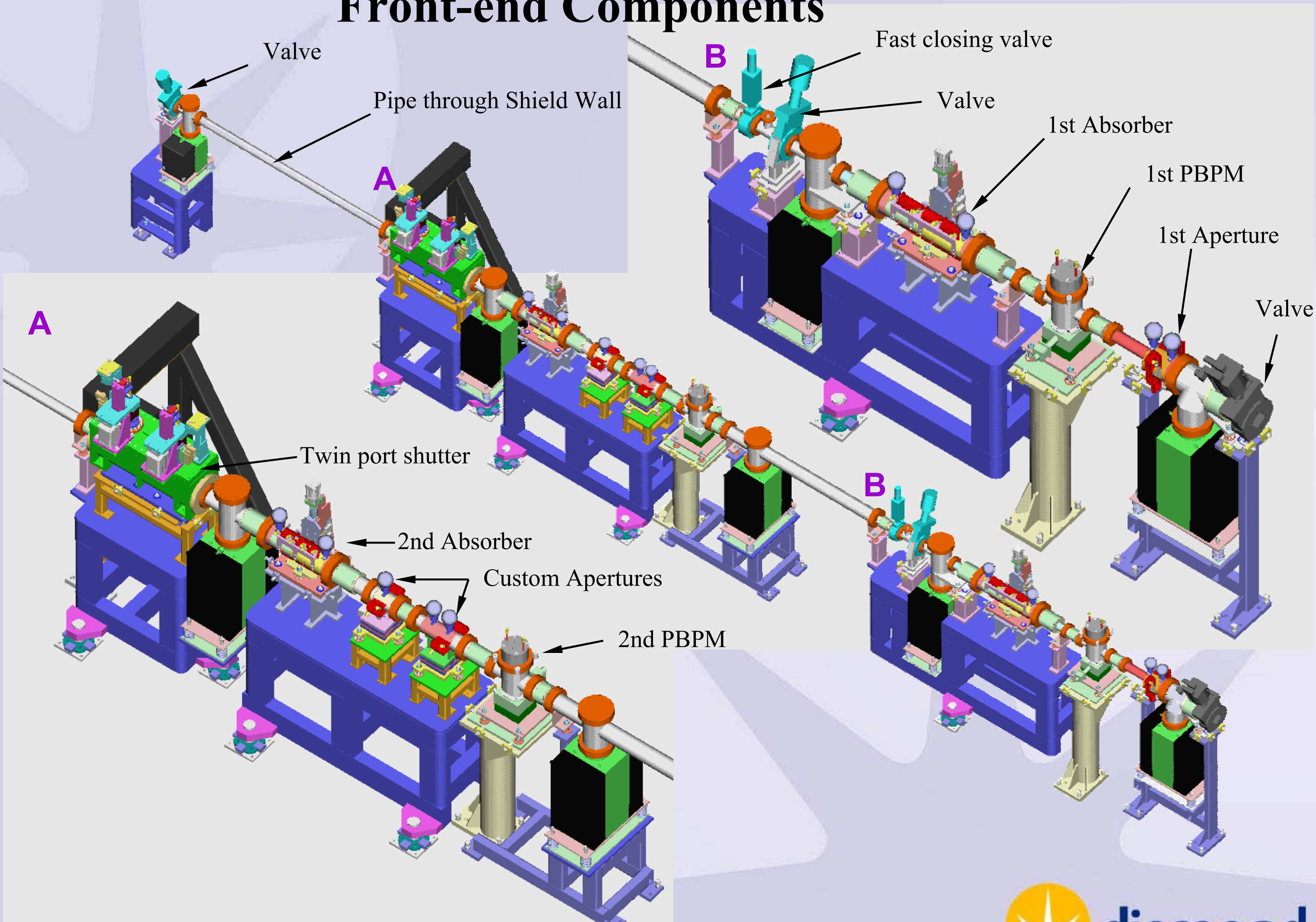
For Standard ID Front-end, this must be reduced to 2mrad x1mrad ID



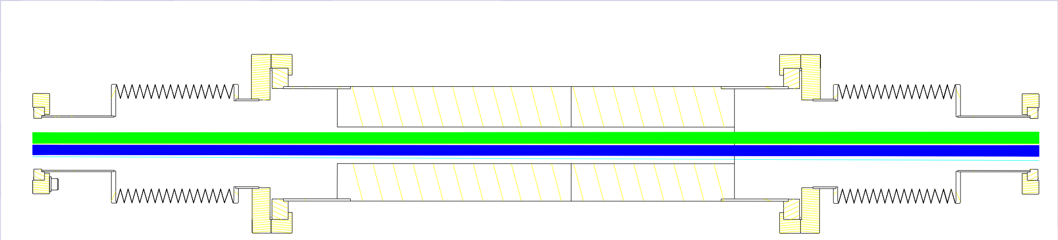
Apertures for Canted Undulators



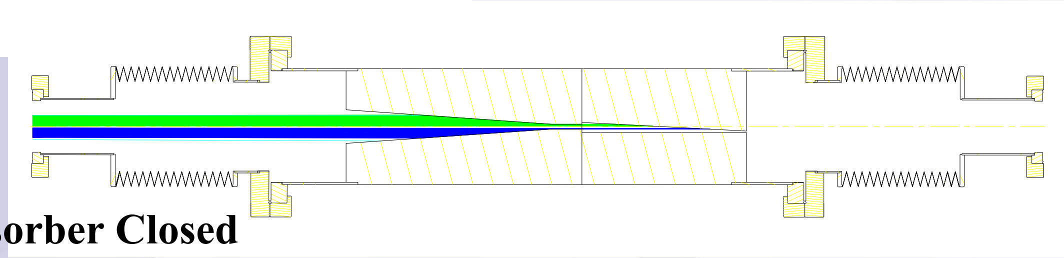
Front-end Components



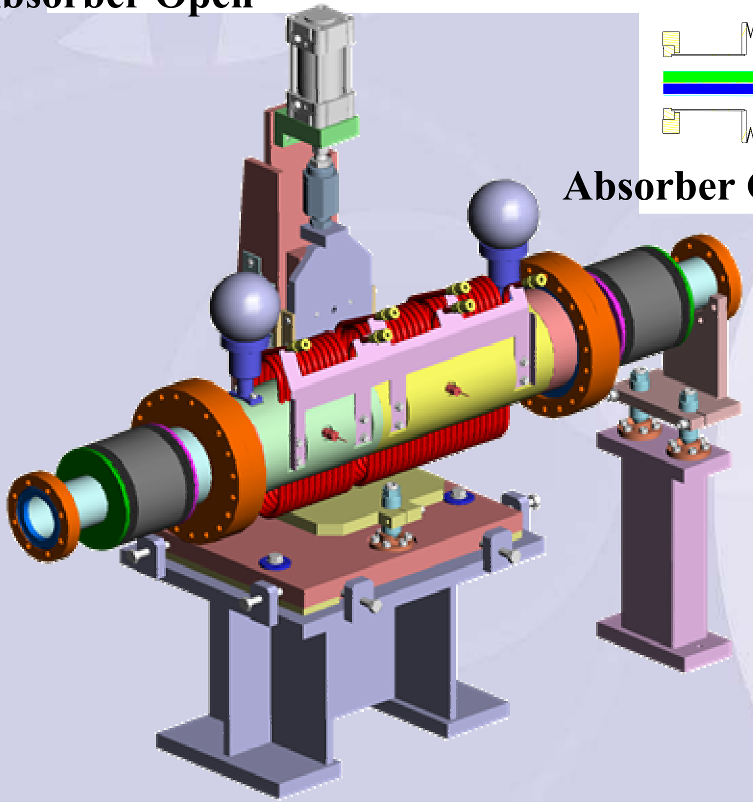
Absorber Design



Absorber Open



Absorber Closed



Pro's

All cooling pipes external to vacuum chamber

All lifting mechanisms easy to access and external to chamber.

Bellows easy to replace

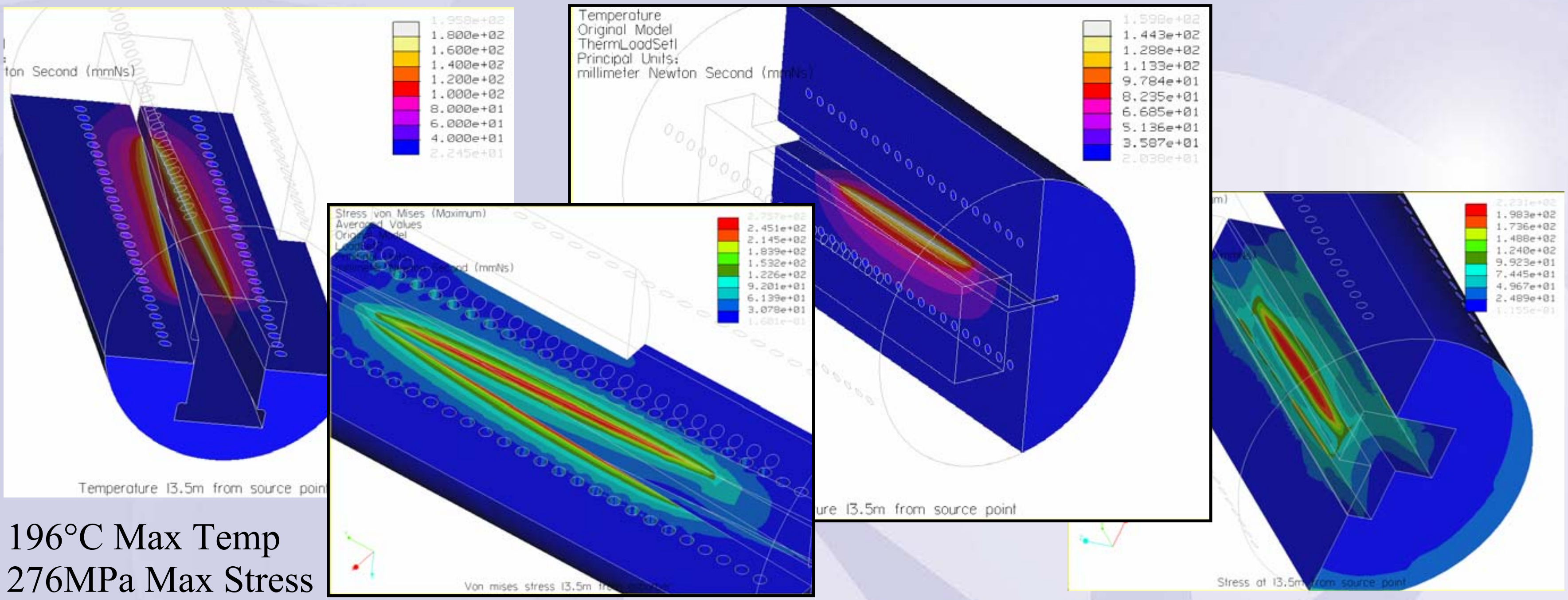
Con's

Vacuum issues have to be considered

Difficult to manufacture if Glidcop used

FEA Results

Power density of 14W/mm^2 @500mA calculated for current design

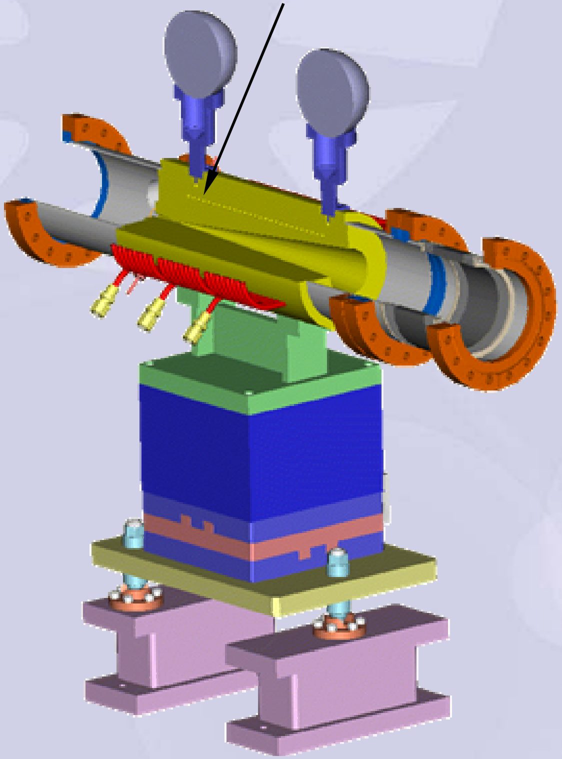


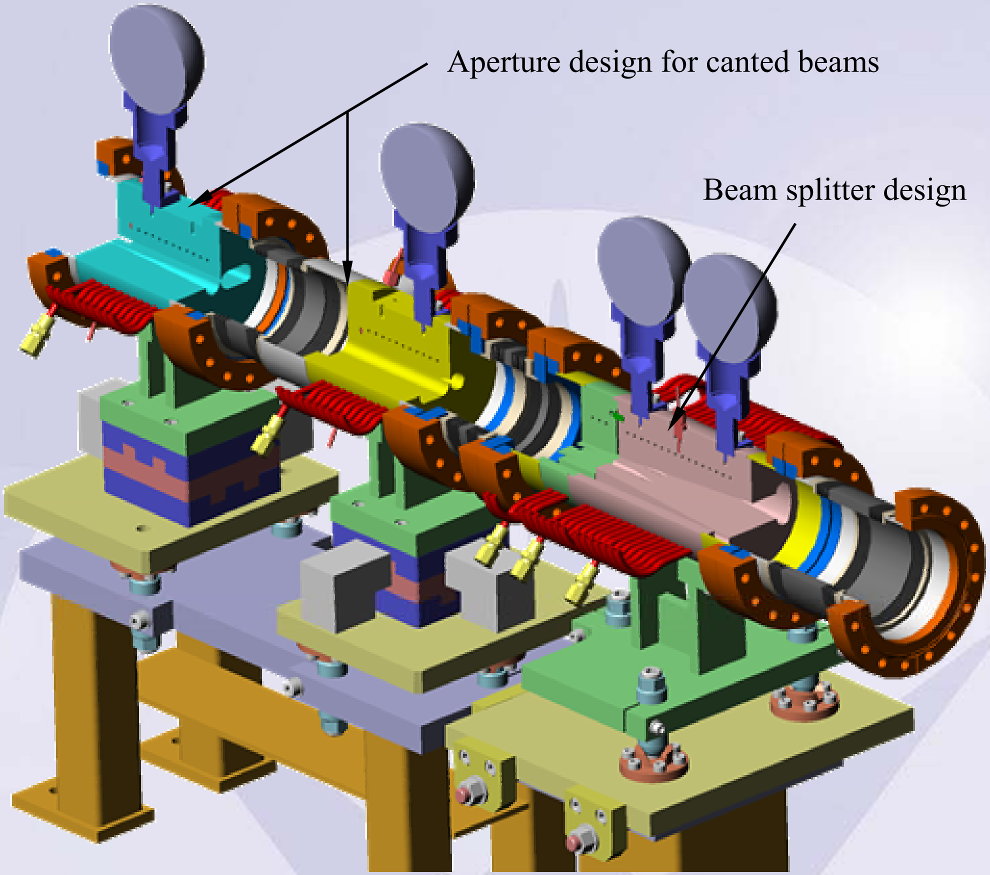
196°C Max Temp
276MPa Max Stress

Max design stress at ESRF is 400MPa for OHFC

Max design stress for Diamond Front-ends 300MPa for OHFC

Customised Aperture designs





Front-end Location

Current status of Front End Design

7 replies have been received from Front-ends tender.

Most are in-budget and timescale (9-15 months)

Design for SCMPW front-end in progress

Recommendations

Leave as much space as practicable between FE and shield wall for access

Reduce beam sizes as much as feasible as early as possible

Consider services requirements as early as possible

XI. Insertion Devices

Strategy:

- Design Permanent Magnet IDs
  - Common support structure for all ID’s, based on Daresbury SRS design with added tapering
  - In– vacuum components based on ESRF design, with SLS Cooled RF taper design
  - Helical ID phase shifting, based on Daresbury SRS design
- Procure major subsystems
  - Support structures
  - Magnets
  - Control Systems
  - Vacuum Components
- Assemble and Test IDs
  - Pre-production : one HU64 and one In-Vac
  - Production: one HU64, two U33, four In-Vac

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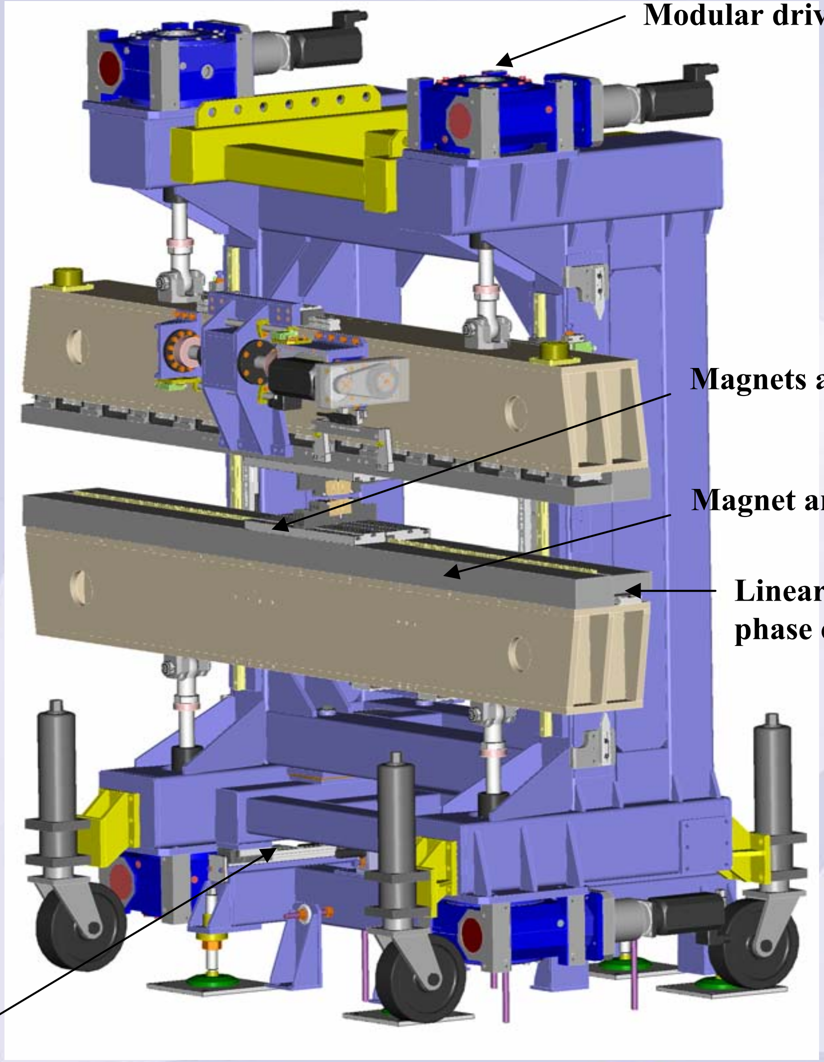
Summary of Phase 1 IDs

- 1 Planar Undulator
  - 2 x 2.4m modules, 33 mm period, 15mm gap
- 1 Helical Undulator
  - 2 x 2.2m modules, with phasing unit between
  - APPLE-2 with 64mm period, 15 mm gap
- 5 In-vacuum Undulators
  - 2m long,
  - 21, 2 x 23, 25, 27 mm period, 7 mm gap
- 1 Superconducting MPW
  - 3.5T, 2m

Helical Undulator - HU64

Not All Magnet Assemblies Shown

• 4 drive motors driven simultaneously to change gap.
• Independent motor drive tapers the gap, maximum taper = 2mm / beam (1mrad)
• Software and tilt sensors control taper.
• Hard limits required between magnet beams and vacuum chamber.
•Gearbox / screw capacity 4 T giving 3.2 T/m for 2.5m array length.
• Diamond specified so far are 0.9 T/m
• Beam mounting surface flatness 20μ/m
• Standard components on all structures. Identical gearboxes, screws (HU64 &U33), motors, encoders, limits and control system.



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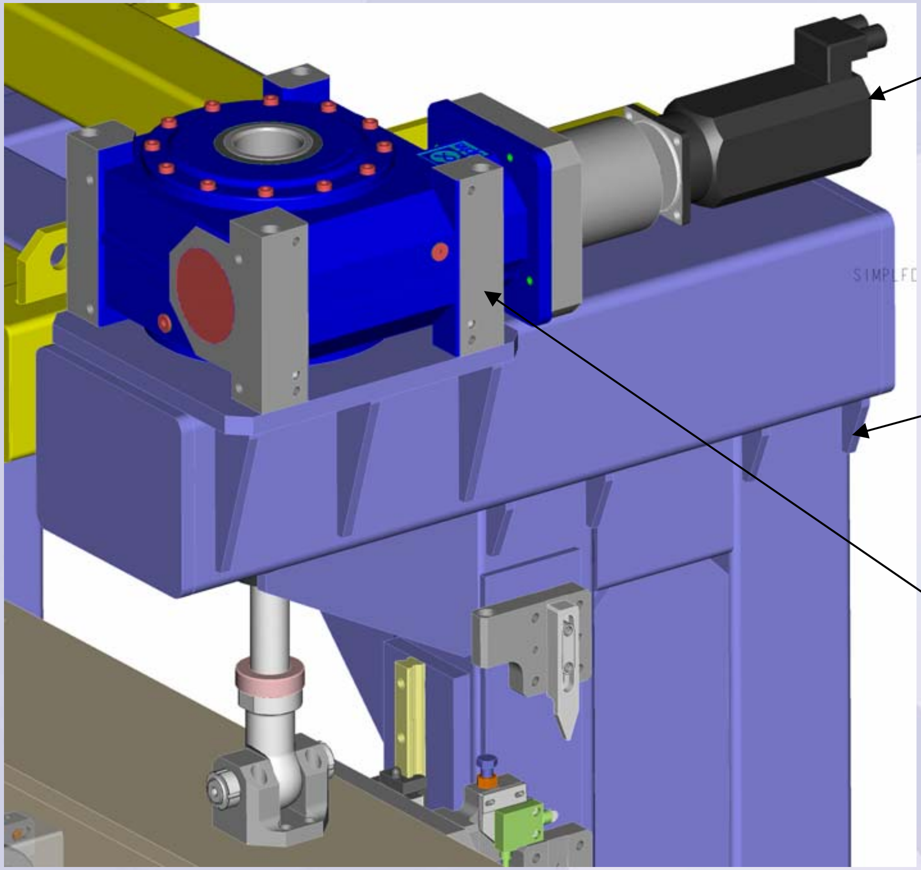
Gap Drive Mechanism



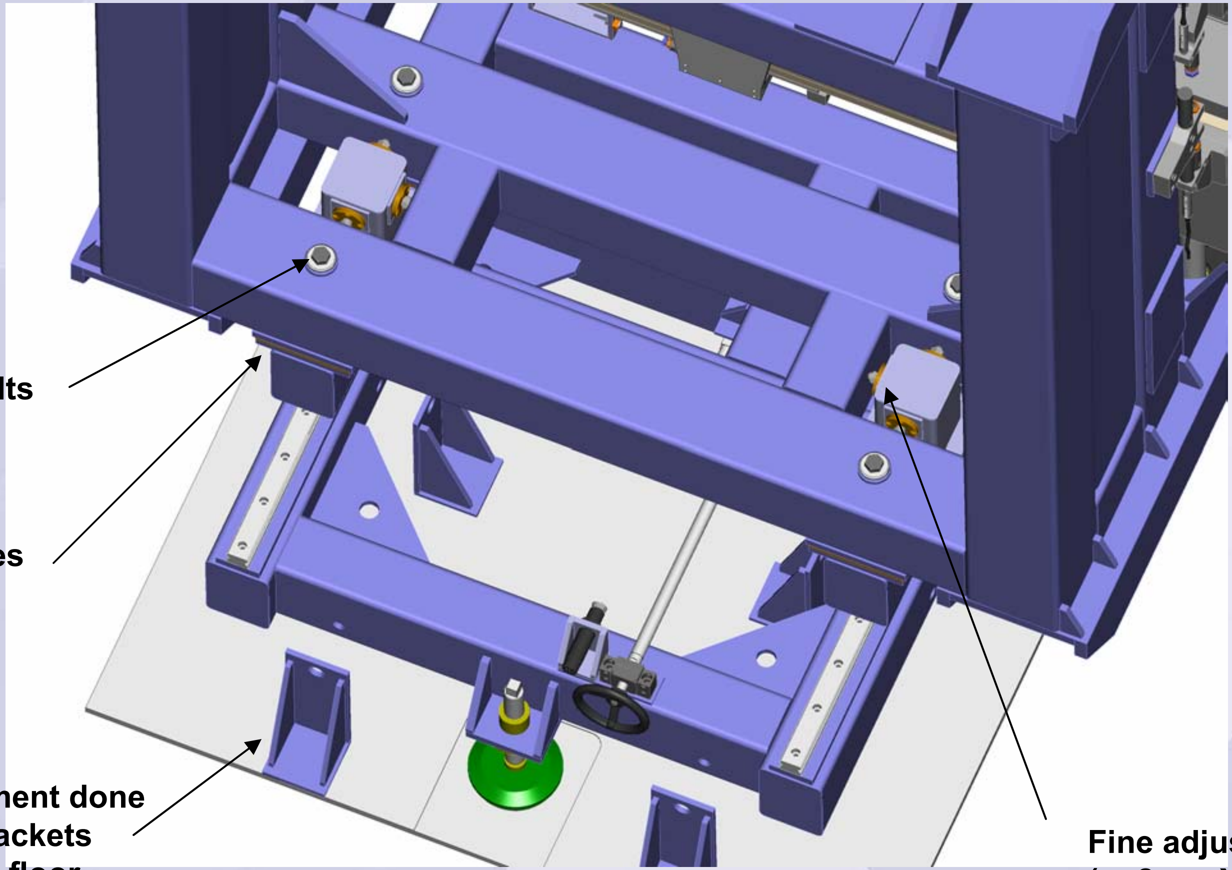
Gearbox / Motor assembly attached to a 40mm dia x 12 lead ballscrew, 4T capacity. Motor and screw identical to phase drive mechanism.

Main frame, fully welded steel structure. Drive components can be removed individually or as a complete assembly.

Alpha VDT100 worm & wheel gearbox. Motor and primary gearbox can be removed with full load applied, will not overhaul.

Overall backlash approx. 3arc min

Base Adjustment



Locking draw bolts

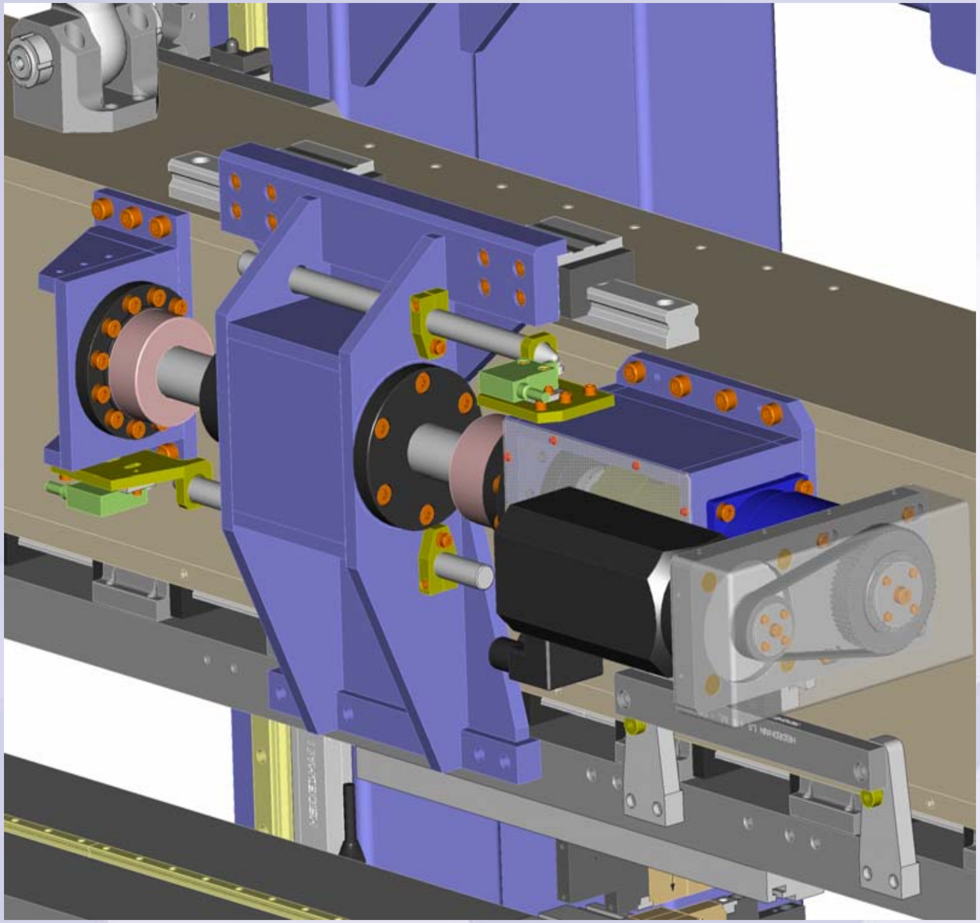
Bronze skid plates

Coarse adjustment done with pusher brackets attached to the floor

Fine adjusting screws. (+- 2mm YX)

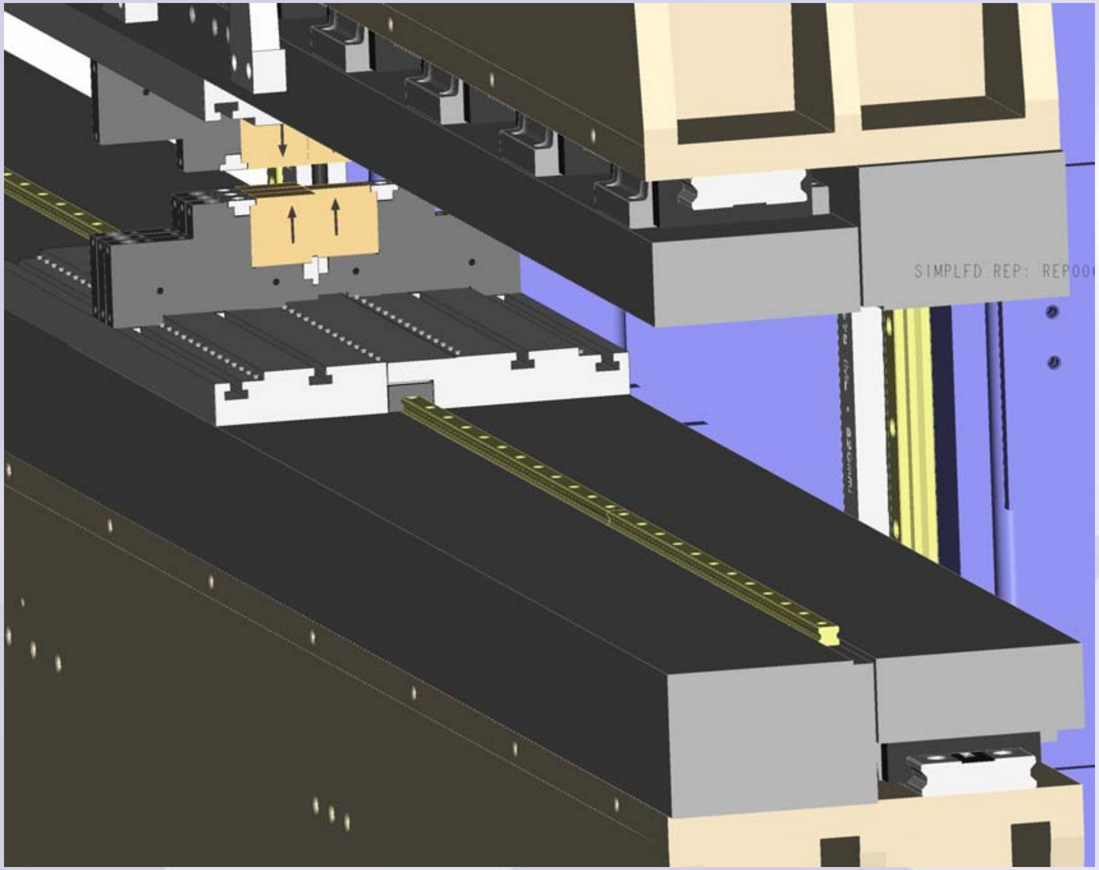
Phase Change Mechanism

- Servo motor drive to a ballscrew with encoder position feedback.
- 4T max capacity.
- Modular construction for easy assembly and replacement.
- Two mechanisms can fit on one beam to drive the phase of a 3 array device.
- Encoder measures the magnet array position directly.
- Motor drives through tooted belt arrangement to keep overall length to a minimum.
- Probe type limit switch actuators easily adjustable to accommodate any stroke up to +- 75mm.



HU64 Magnet holders and phase rail system

- Additional linear rail directly under the magnets to control forces in the ‘Y’ direction.
- Sub-plates used to carry magnet holder location and fastener features.

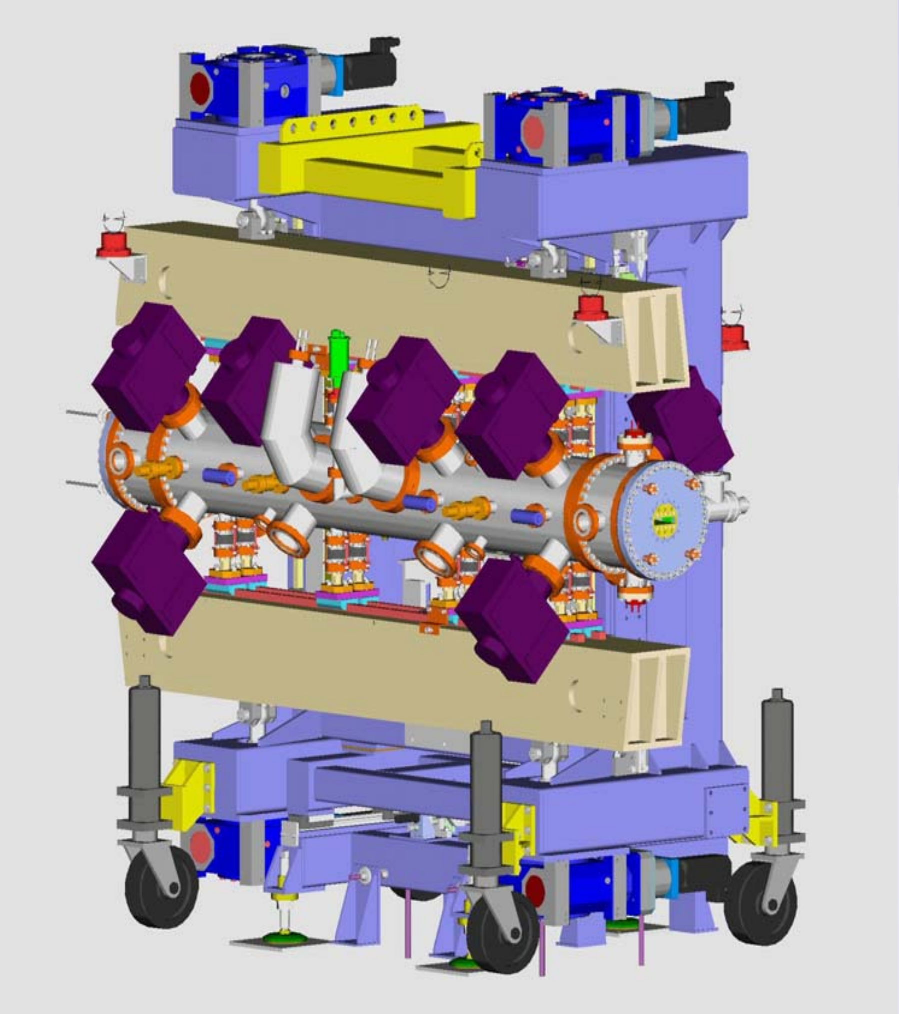


In-vacuum Undulators

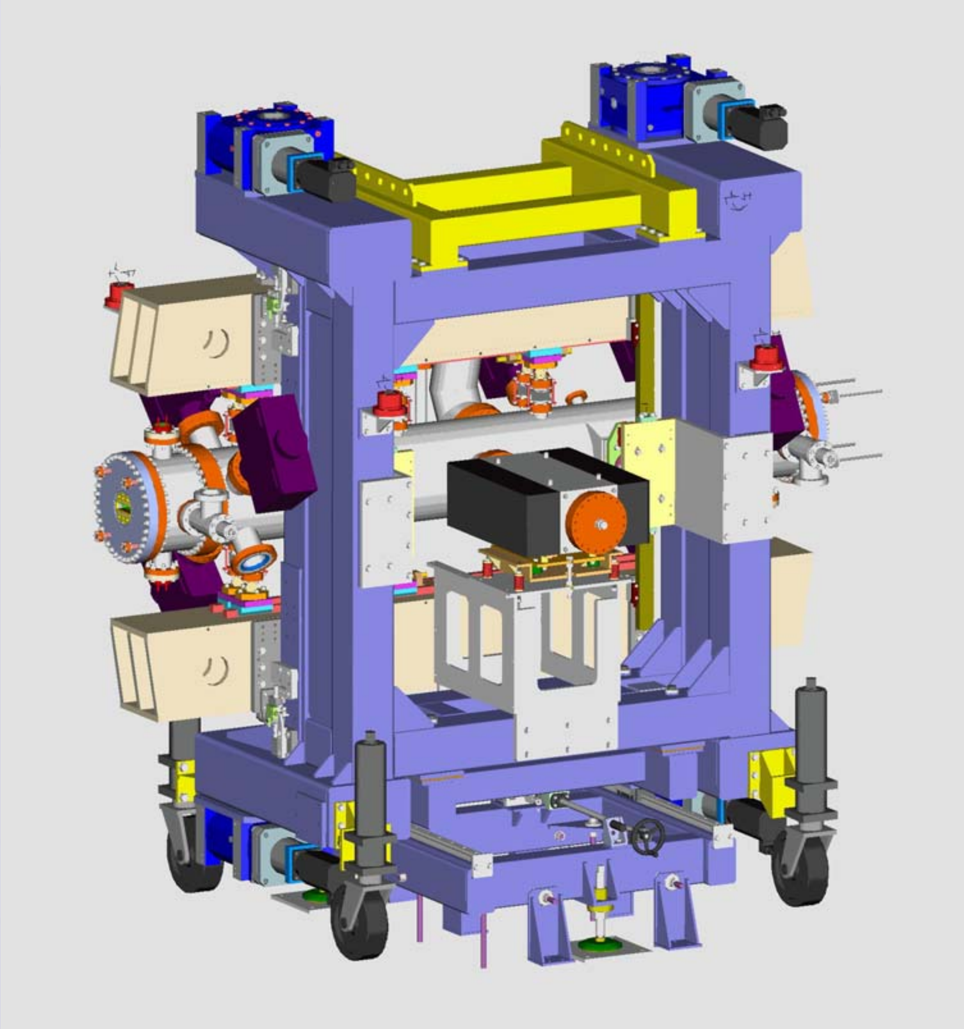
- 2m long, 21, 2 x 23, 25 and 27 mm period
- 7 mm minimum gap
- Samarium Cobalt magnets
- Tapering

Standard support structure with :-

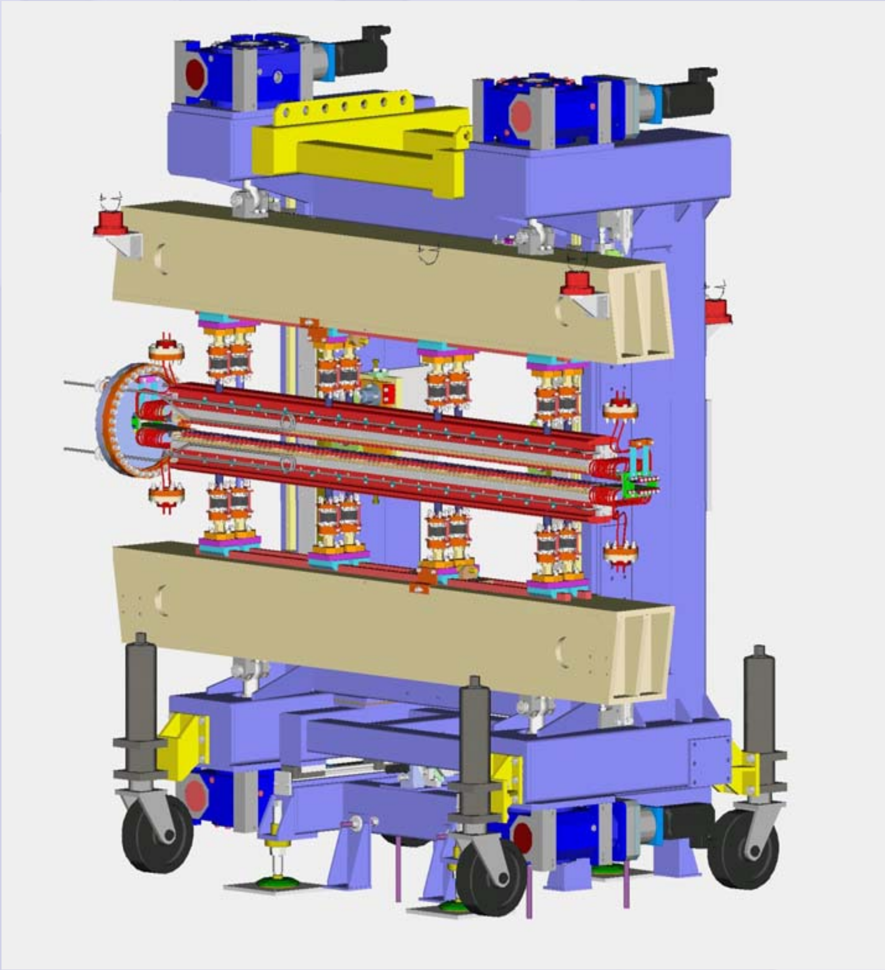
  - magnet array and vacuum system as for ESRF
  - Cooled flexible tapers as for SLS
  - 4 mm minimum gap possible

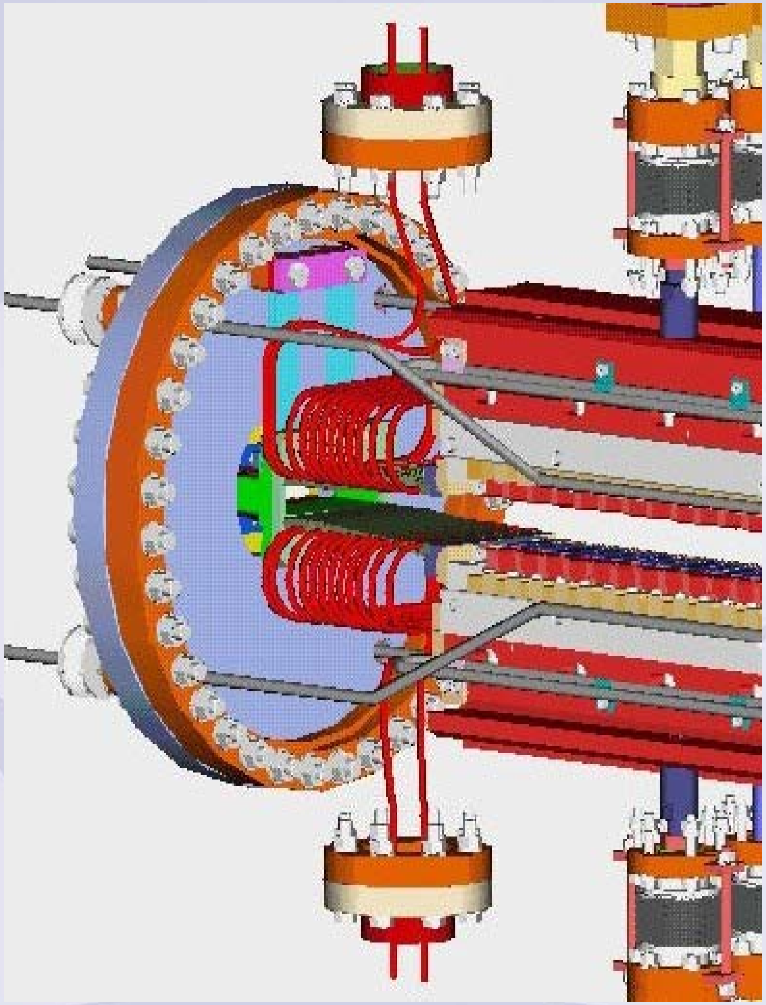


In-vacuum Undulators



In-vacuum Undulator





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Forces on structure (kN)

	Vertical	Along beam	across beam
Design	48	40	40
HU64	14.2	23.5	21.8
U23IV	17.5		

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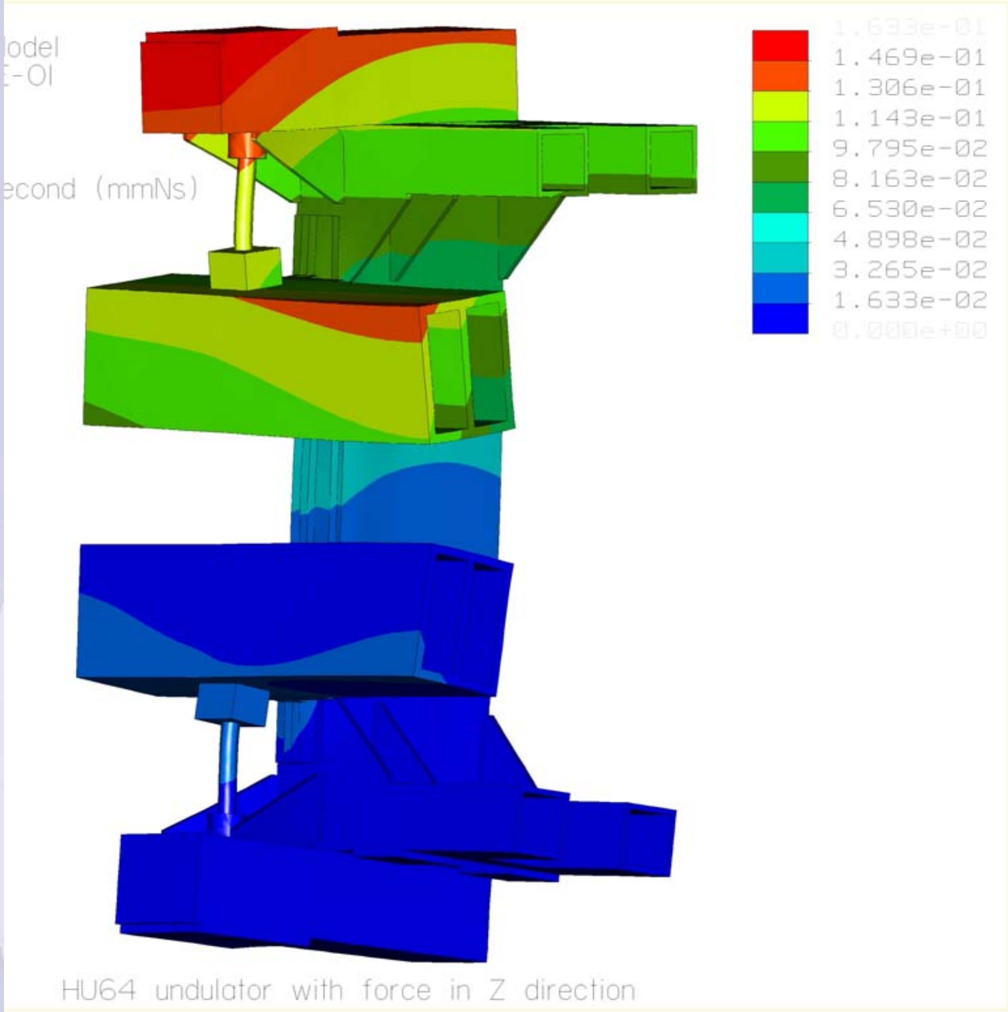
FEA of Structure

- Vertical Force 48 kN
- Max deflection 0.15mm at top of structure
- Net vertical deflection over 80mm width at pole:

    28μm top array

    14μm bottom array



ID Laboratory

- ID Test Area - ~18 x 8m
  - floor isolated to reduce vibration from rest of building
- ID Assembly Area - ~14 x 8m
  - All suitable for in vacuum undulators
- Storage Area - ~4 x 8m
- Measurement bench of 5.5m measurement length with integral coil system will be supplied by ESRF

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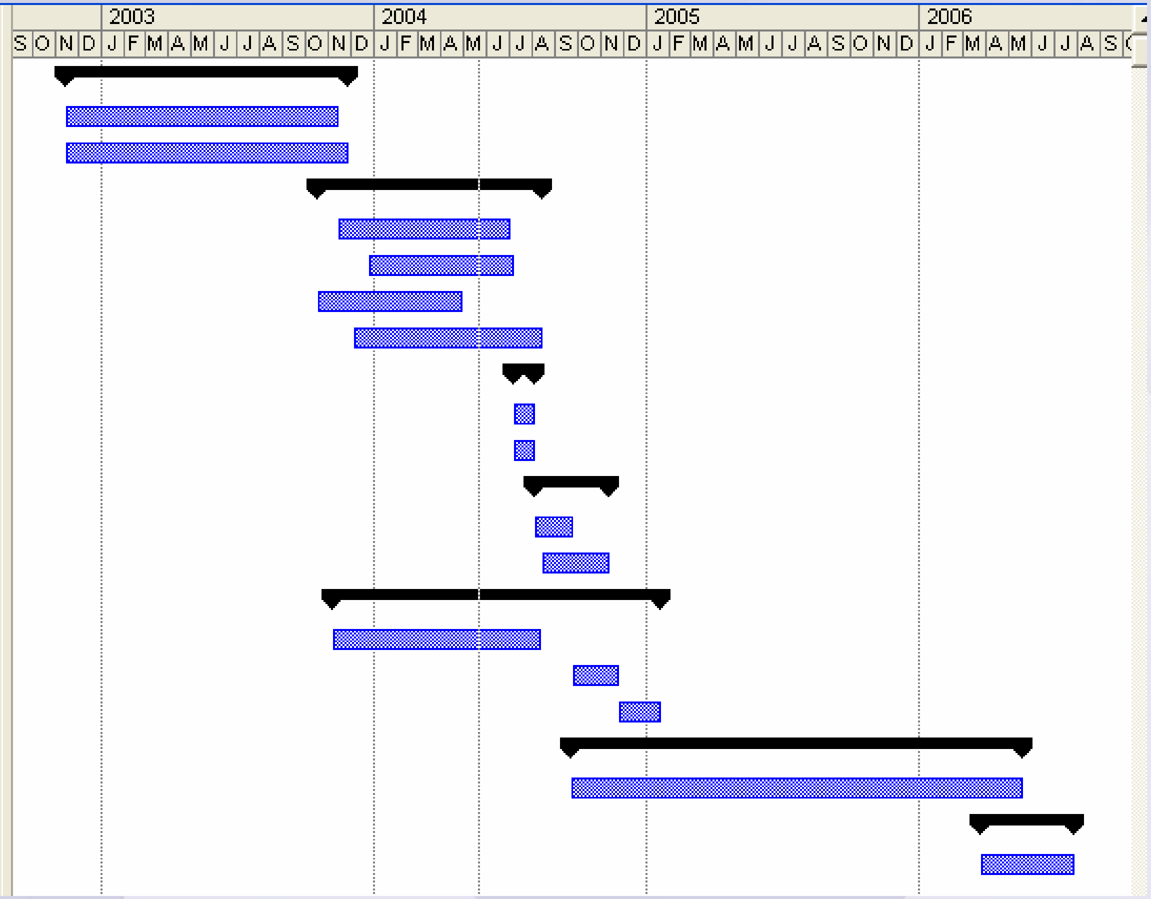
Timescales

	Task Name
1	DESIGN
2	Support Structure Design
3	Control System Design
4	PRE PRODUCTION PROCURE
5	Pre Production Supports (HU64 & U23IVa) Procure
6	Pre Production Control System Procure
7	HU64 Magnets Procure
8	U23IVa Magnets Procure
9	PRE PRODUCTION INTEGRATION
10	HU64 Integration
11	U23IVa Integration
12	PRE PRODUCTION ASSEMBLE AND TEST
13	HU64 Assemble & Test
14	U23IVa Assemble & test
15	PRE PRODUCTION MAGNET SHIMMIMG
16	Measuring Bench Procure
17	HU64 Magnet Shimming
18	U23IVa Magnet Shimming
19	PRODUCTION
20	Production Procure, assemble, test, shim
21	INSTALL
22	Install IDs



Additional Information

- Elizabeth Duke of Diamond gave a presentation with more information about individual beamlines at the NSLS II Workshop, March 15, 2004 (see http://www.nsls2.bnl.gov/newsroom/workshops/2003/NSLS-II/presentations/Duke_Crystallography.pdf)
- This presentation is in the OPS DIV/OPS DIV Workspace/Upgrade Information Exchange/General Notes folder.